US011445659B2

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Koch et al.

(10) **Patent No.: US 11,445,659 B2**
(45) **Date of Patent: *Sep. 20, 2022**

(54) **CROP INPUT VARIETY SELECTION SYSTEMS, METHODS, AND APPARATUS**

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(72) Inventors: **Dale Koch**, Tremont, IL (US); **Todd Swanson**, Morton, IL (US)

(73) Assignee: **Precision Planting LLC**, Tremont, IL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 259 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/857,615**

(22) Filed: **Apr. 24, 2020**

(65) **Prior Publication Data**

US 2020/0245530 A1 Aug. 6, 2020

Related U.S. Application Data

(63) Continuation of application No. 15/889,180, filed on Feb. 5, 2018, now Pat. No. 10,667,460, which is a continuation of application No. 14/832,804, filed on Aug. 21, 2015, now Pat. No. 9,883,625.

(60) Provisional application No. 62/088,411, filed on Dec. 5, 2014, provisional application No. 62/040,205, filed on Aug. 21, 2014.

(51) **Int. Cl.**

A01C 7/10 (2006.01)
A01C 21/00 (2006.01)
A01C 7/04 (2006.01)
A01C 7/08 (2006.01)

(52) **U.S. Cl.**

CPC ***A01C 7/102*** (2013.01); ***A01C 7/046*** (2013.01); ***A01C 21/005*** (2013.01); *A01C 7/081* (2013.01)

(58) **Field of Classification Search**

CPC A01C 7/102; A01C 7/046; A01C 7/081; A01C 21/005; A01C 7/10; A01C 7/08; A01C 7/00; A01C 7/044; A01C 7/042; A01C 7/04; A01C 21/00

See application file for complete search history.

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10,667,460 B2 * 6/2020 Koch A01C 21/005
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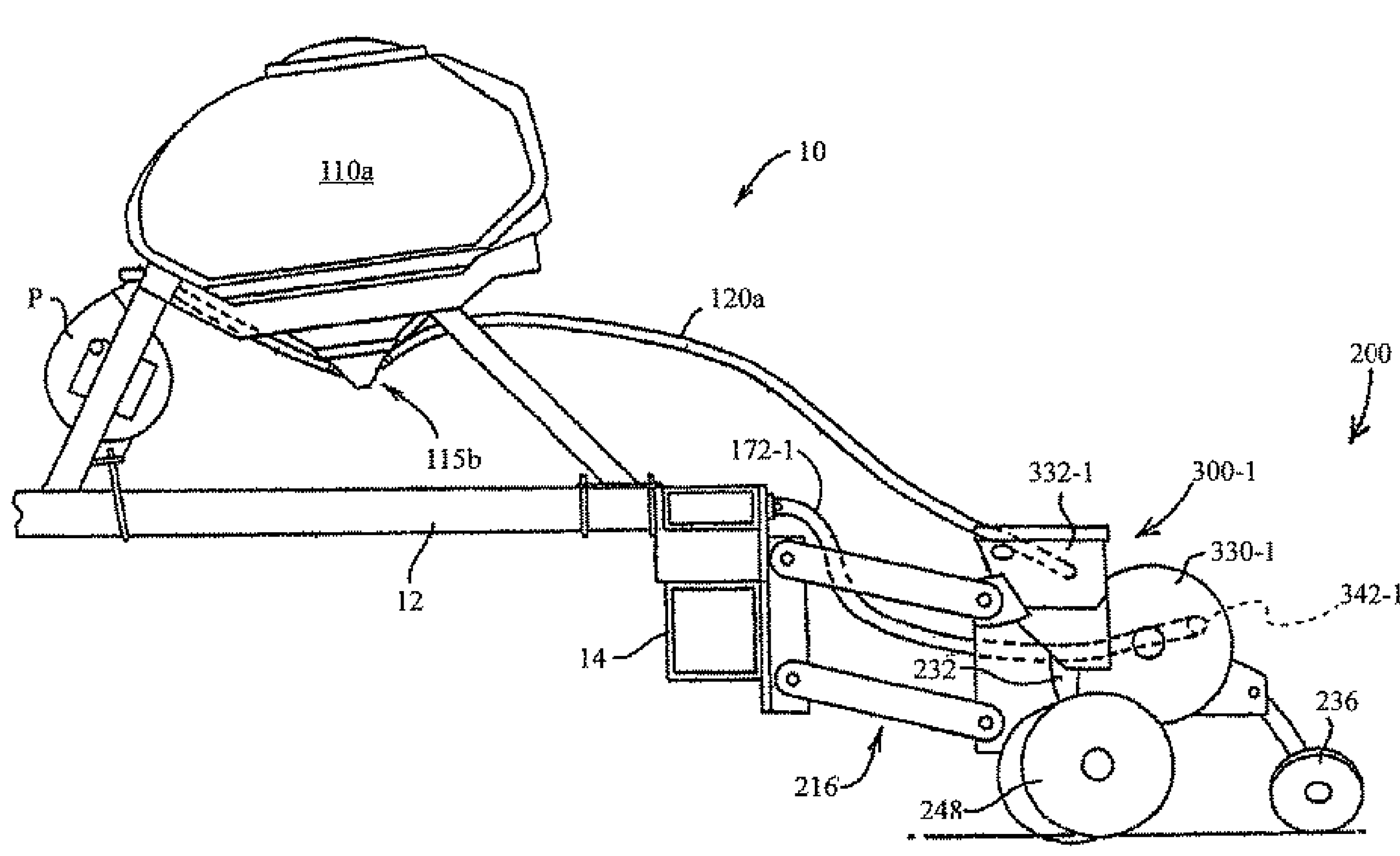
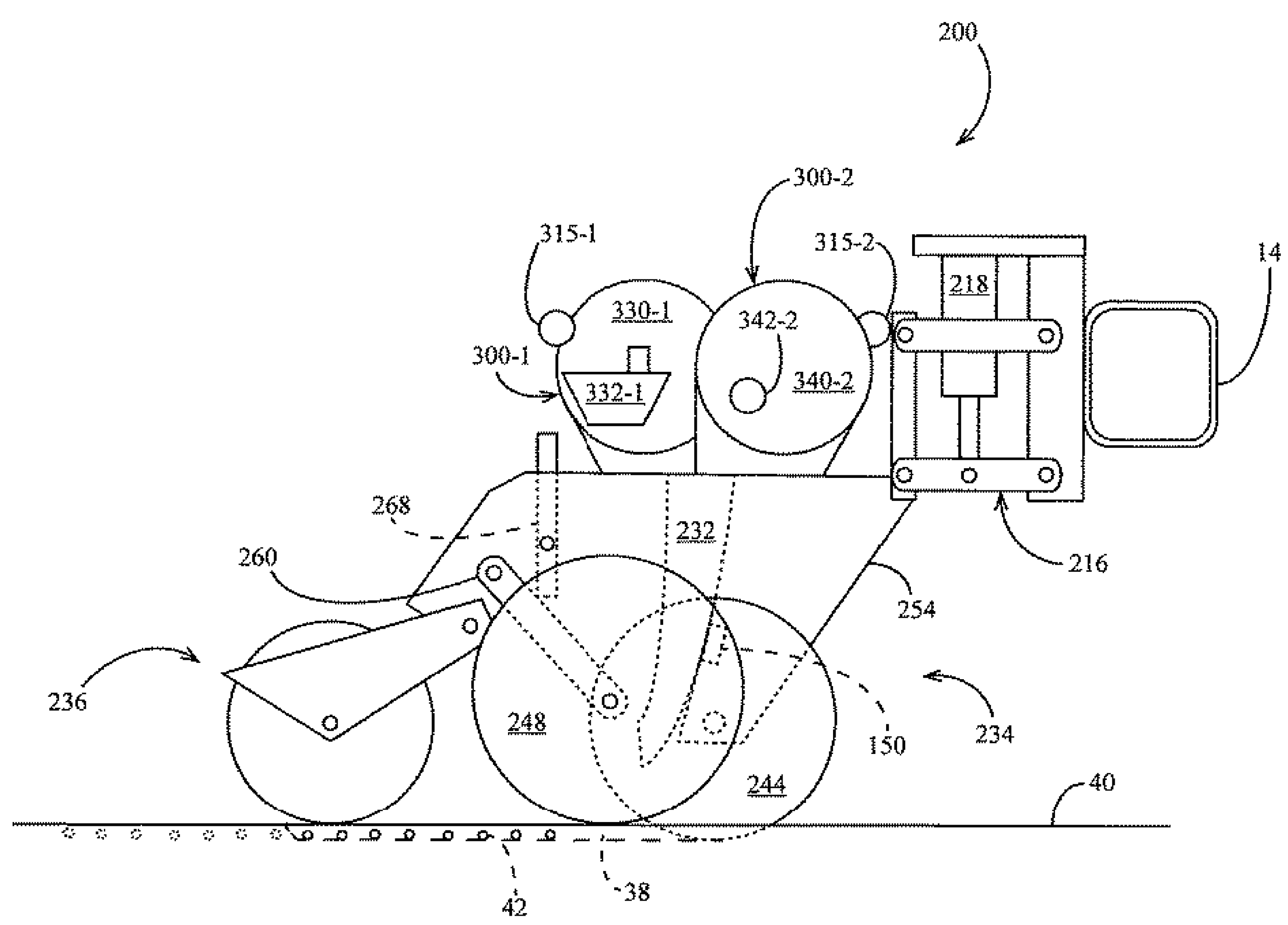
Primary Examiner — Christopher J. Novosad

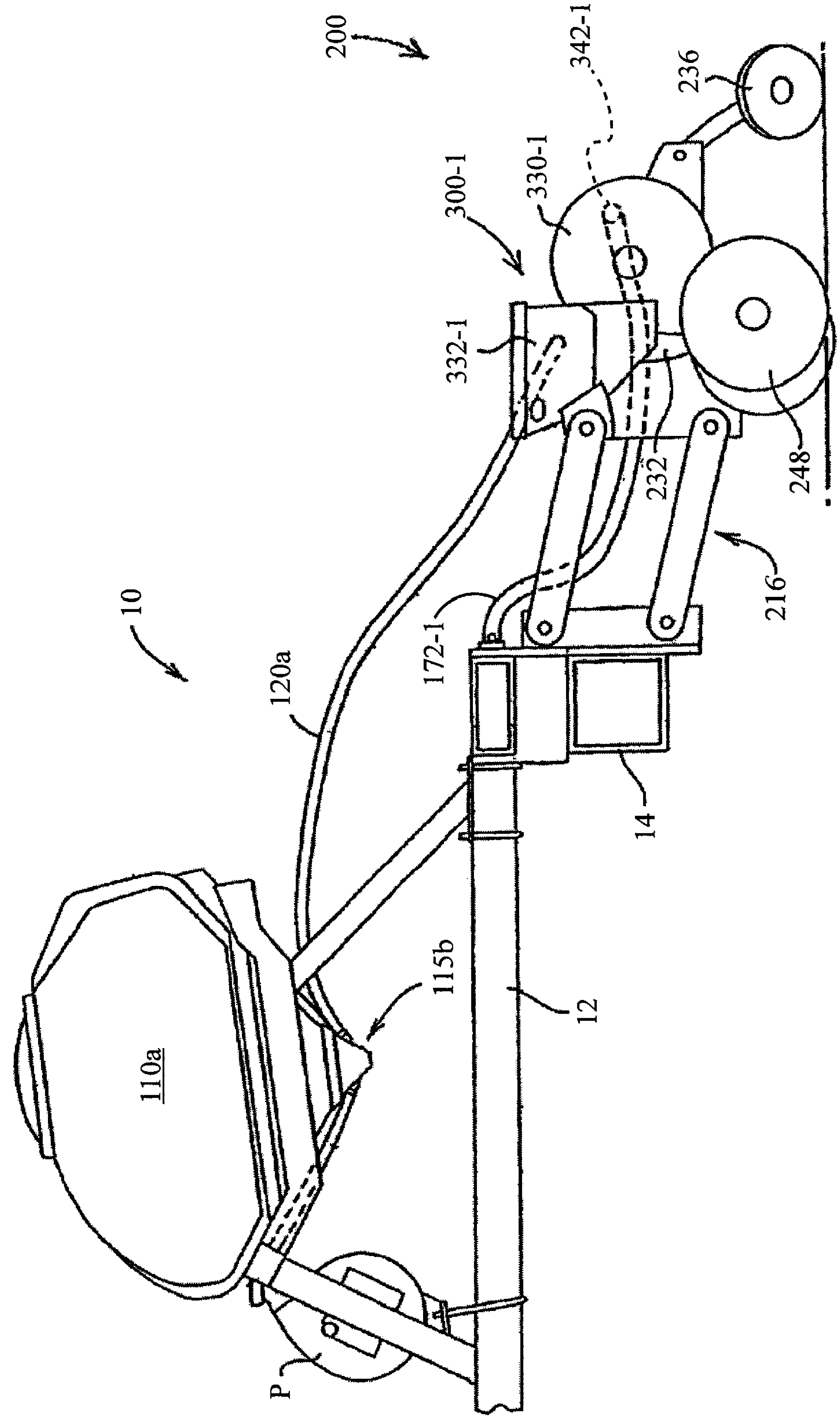
(57) **ABSTRACT**

Systems, methods, and apparatus for selecting an agricultural input include and second seed meters that selectively meter seed from first and second sources, respectively, into a common planting trench. In some embodiments, the seed meters are selectively operated by electric motors controlled with reference to a seed type prescription. In some embodiments, the first and second seed meters deposit seeds along a common plane.

20 Claims, 33 Drawing Sheets



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342-1
236
300-1
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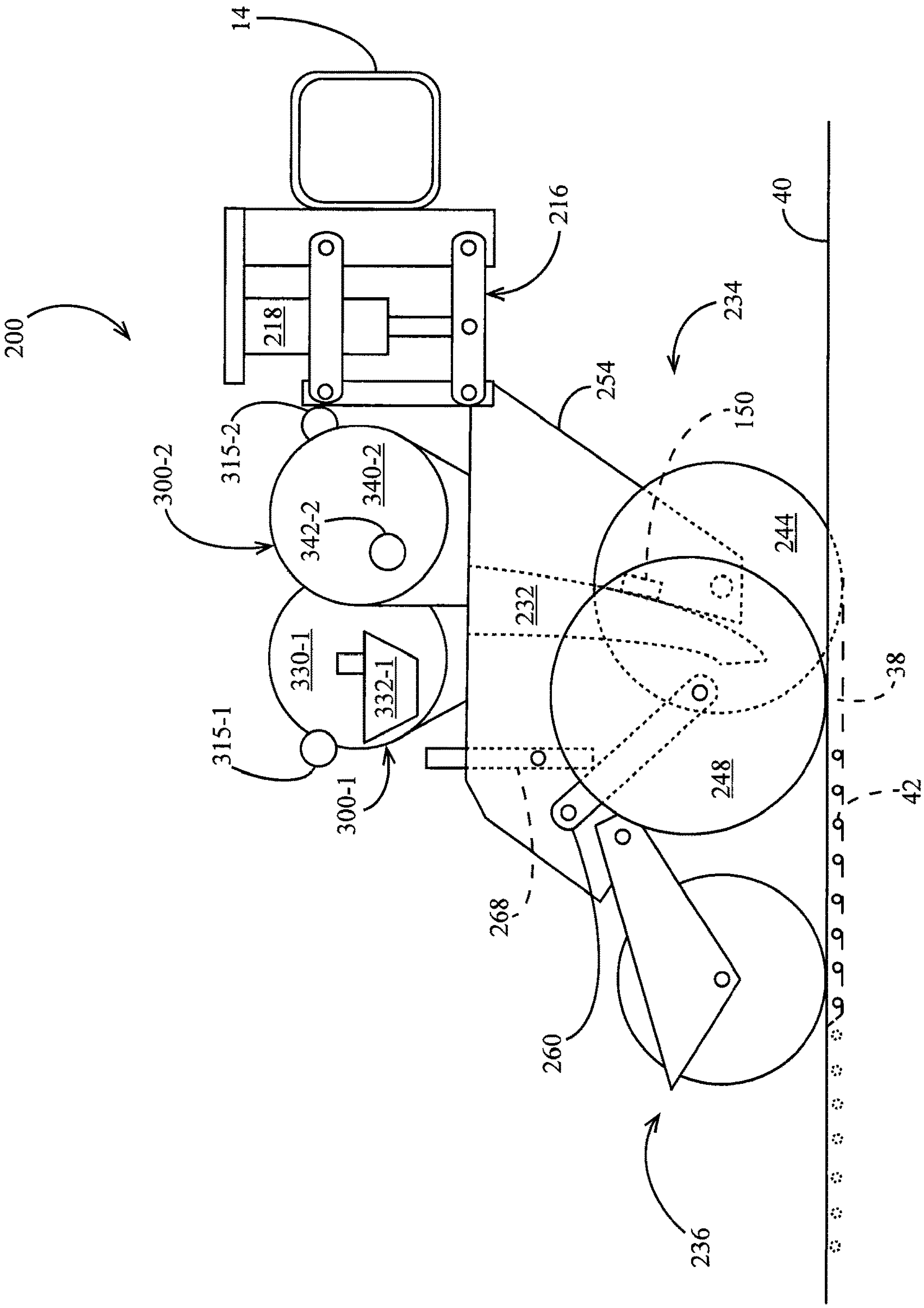
232
248
216
10
120a
172-1
14
115b
110a
12
P

FIG. 1


14
200
216
218
234
254
150
40
300-2
315-2
340-2
342-2
244
232
330-1
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315-1
300-1
38
248
42
268
260
236

FIG. 2

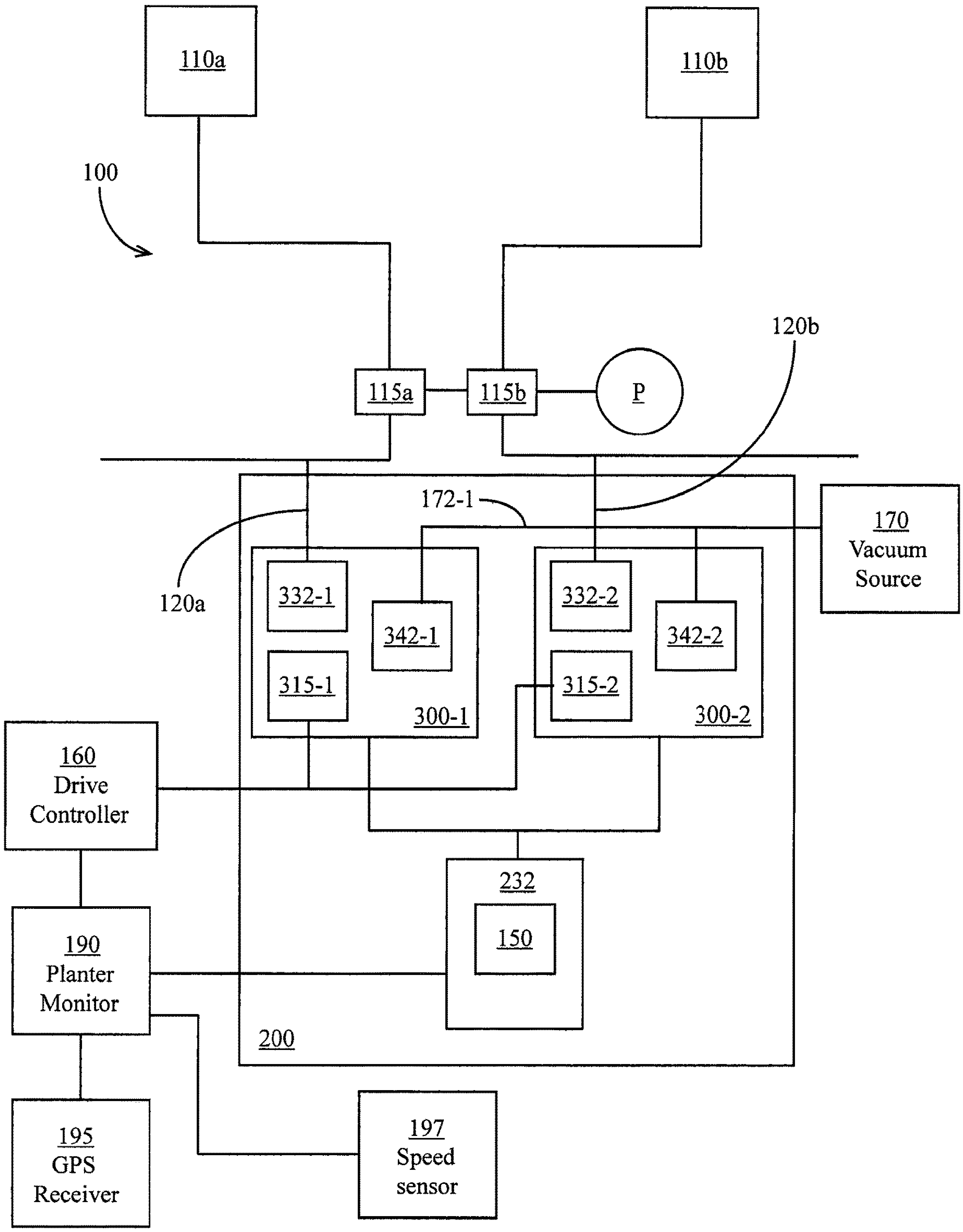

110a
110b
100
120b
115a
115b
P
172-1
170
Vacuum
Source
120a
332-1
342-1
315-1
300-1
332-2
342-2
315-2
300-2
160
Drive
Controller
232
150
190
Planter
Monitor
200
195
GPS
Receiver
197
Speed
sensor

FIG. 3

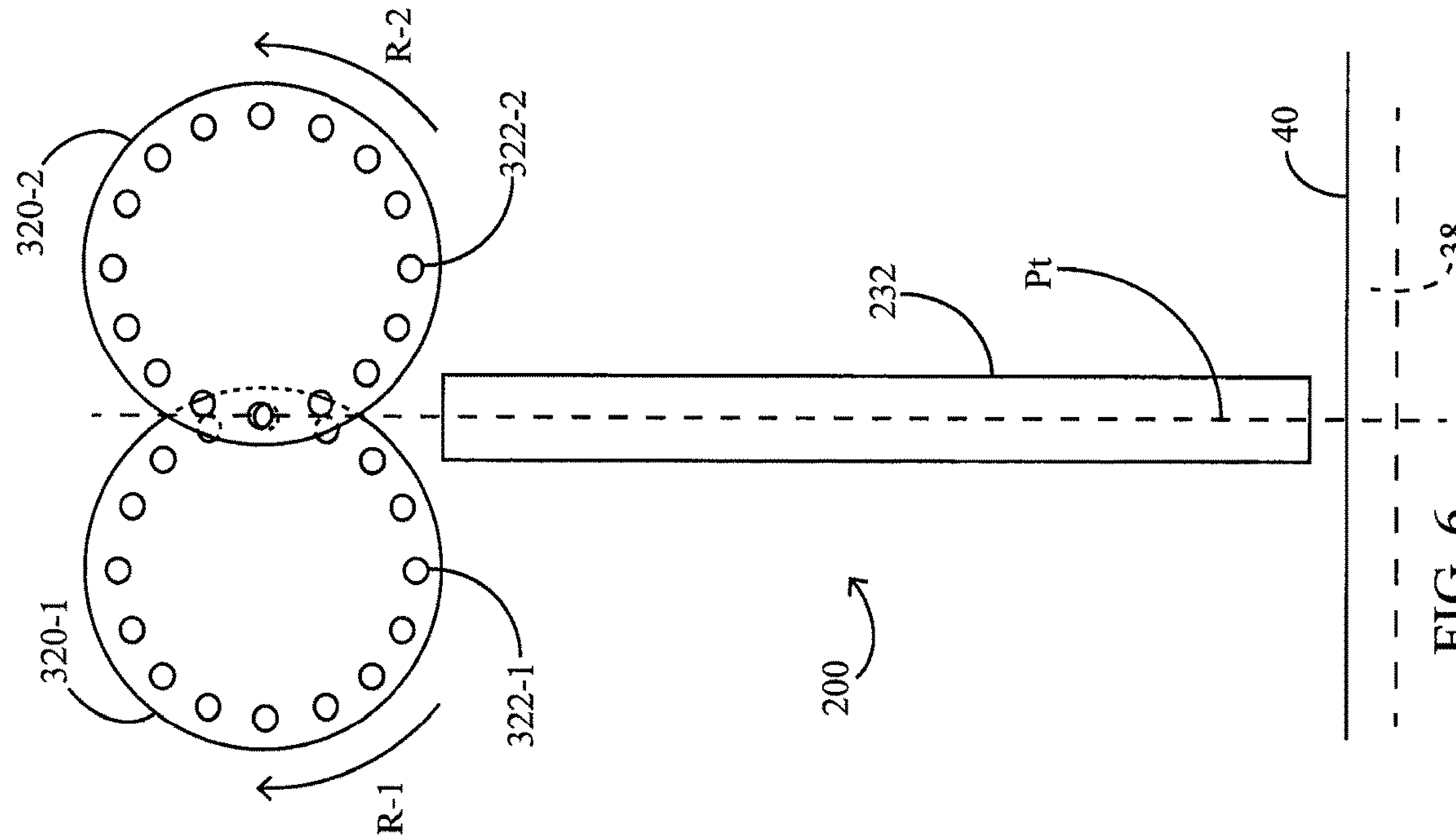
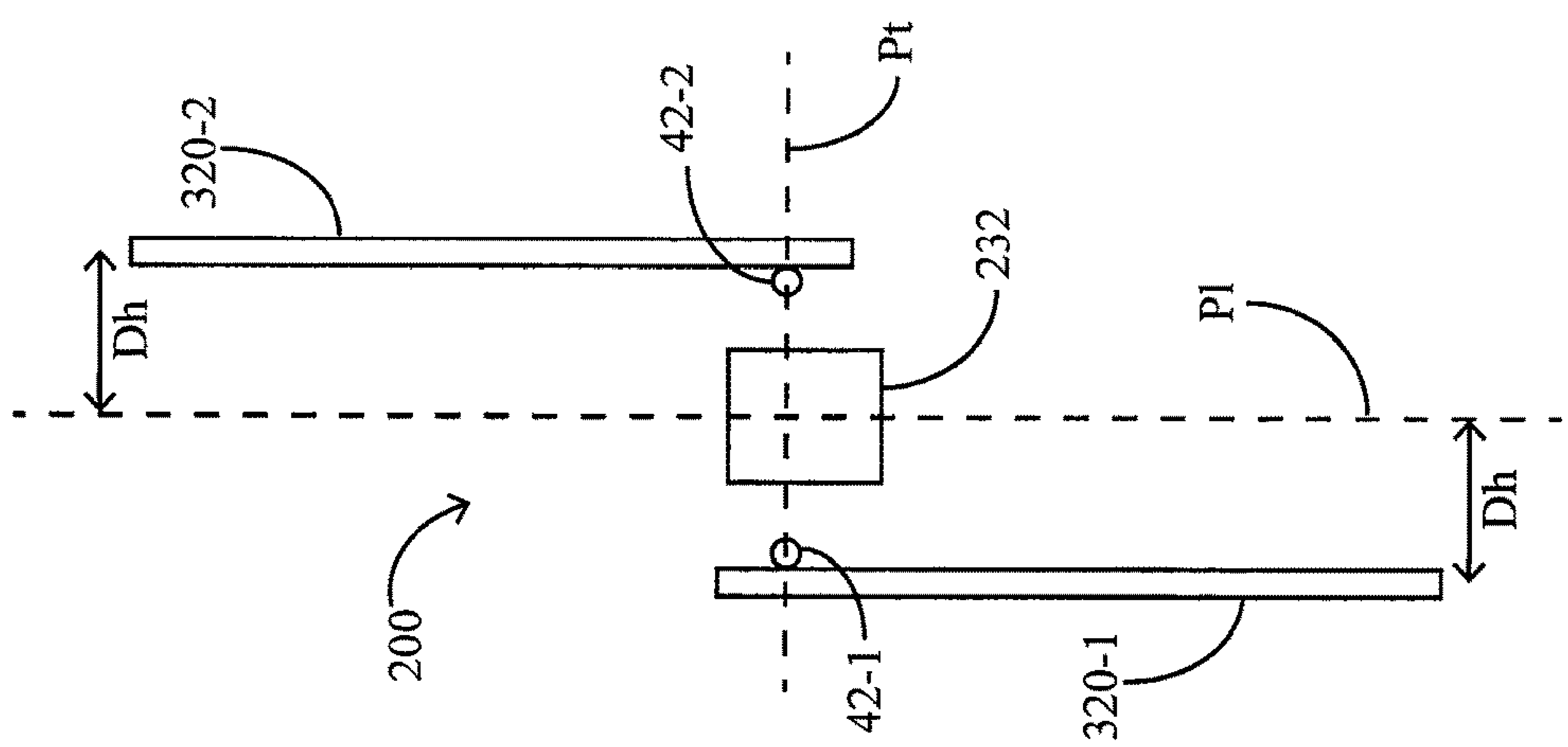


FIG. 6



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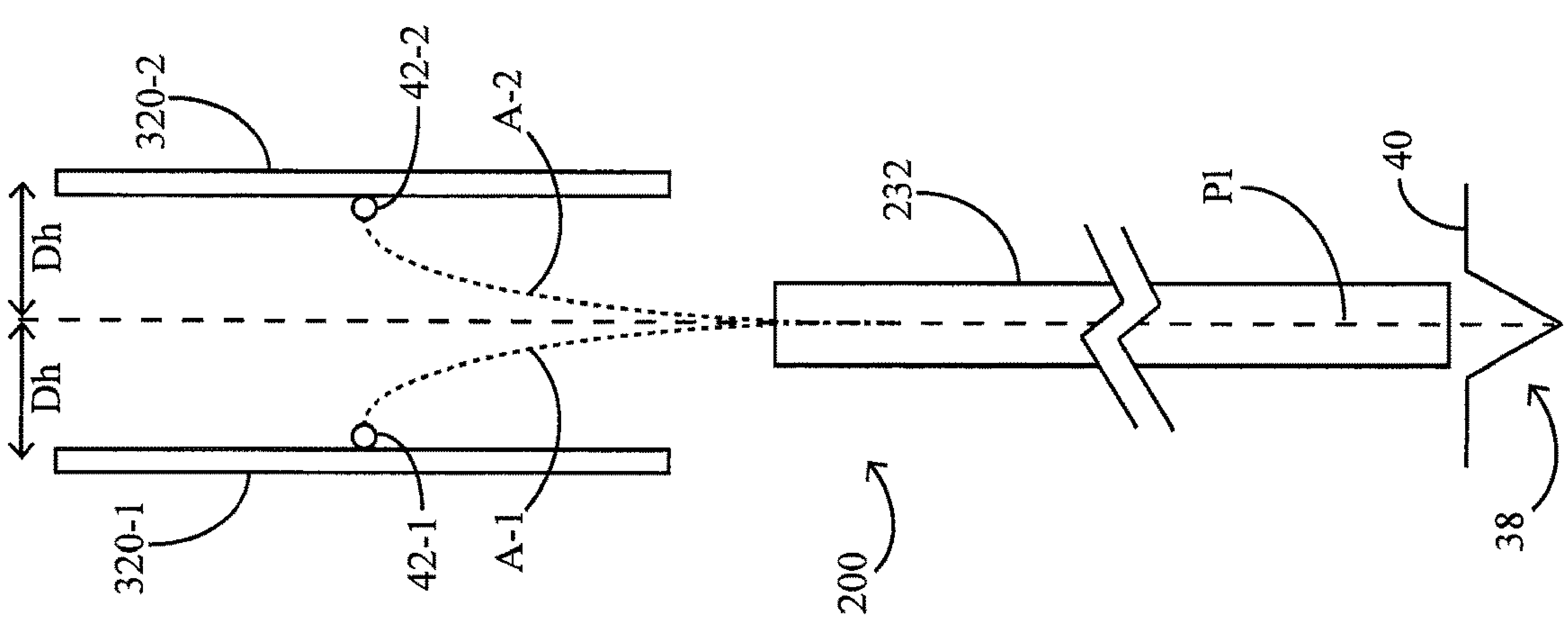

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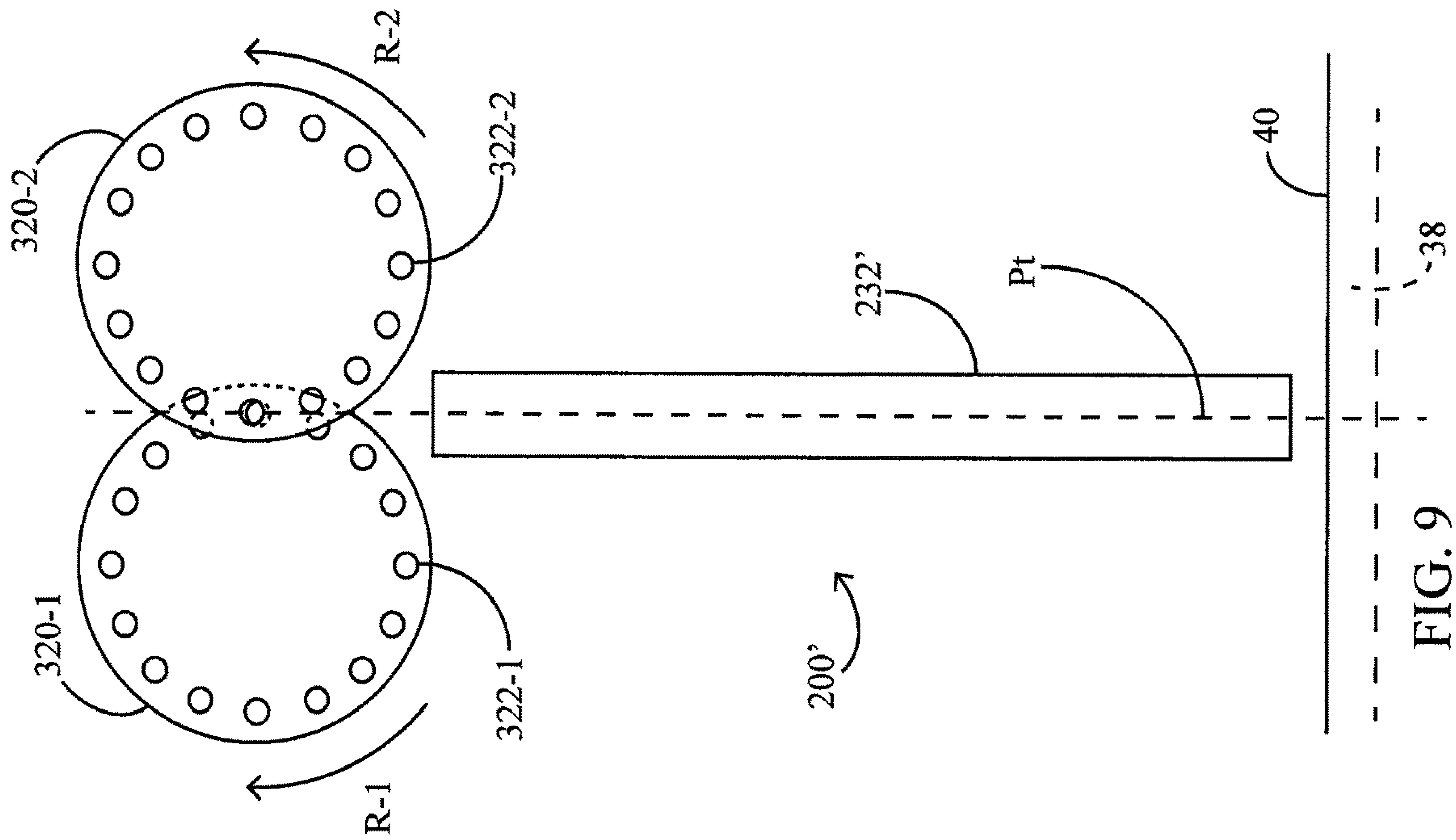


FIG. 9

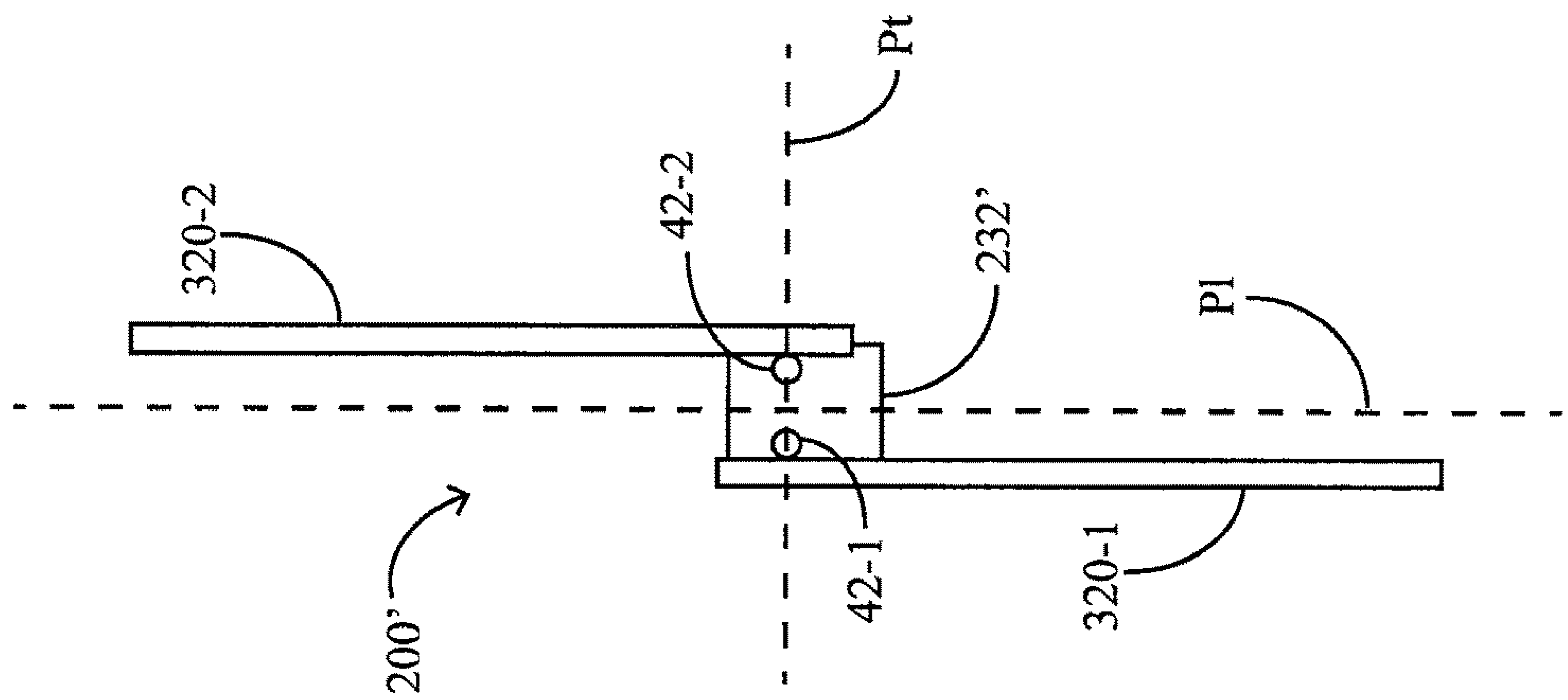


FIG. 8

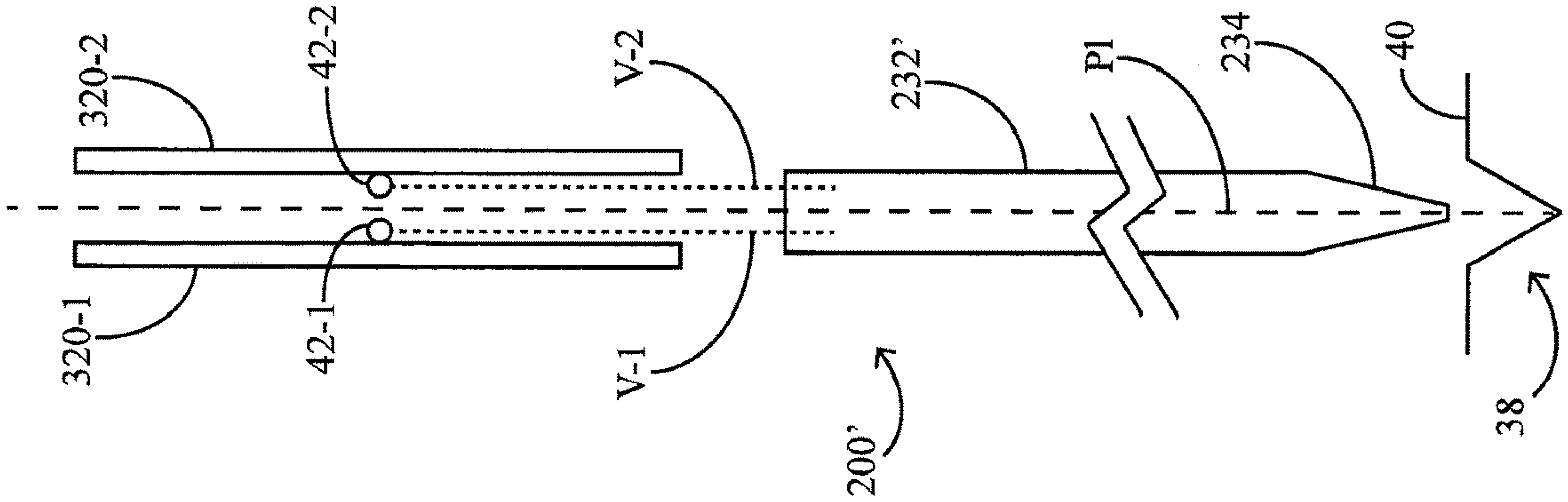


FIG. 7

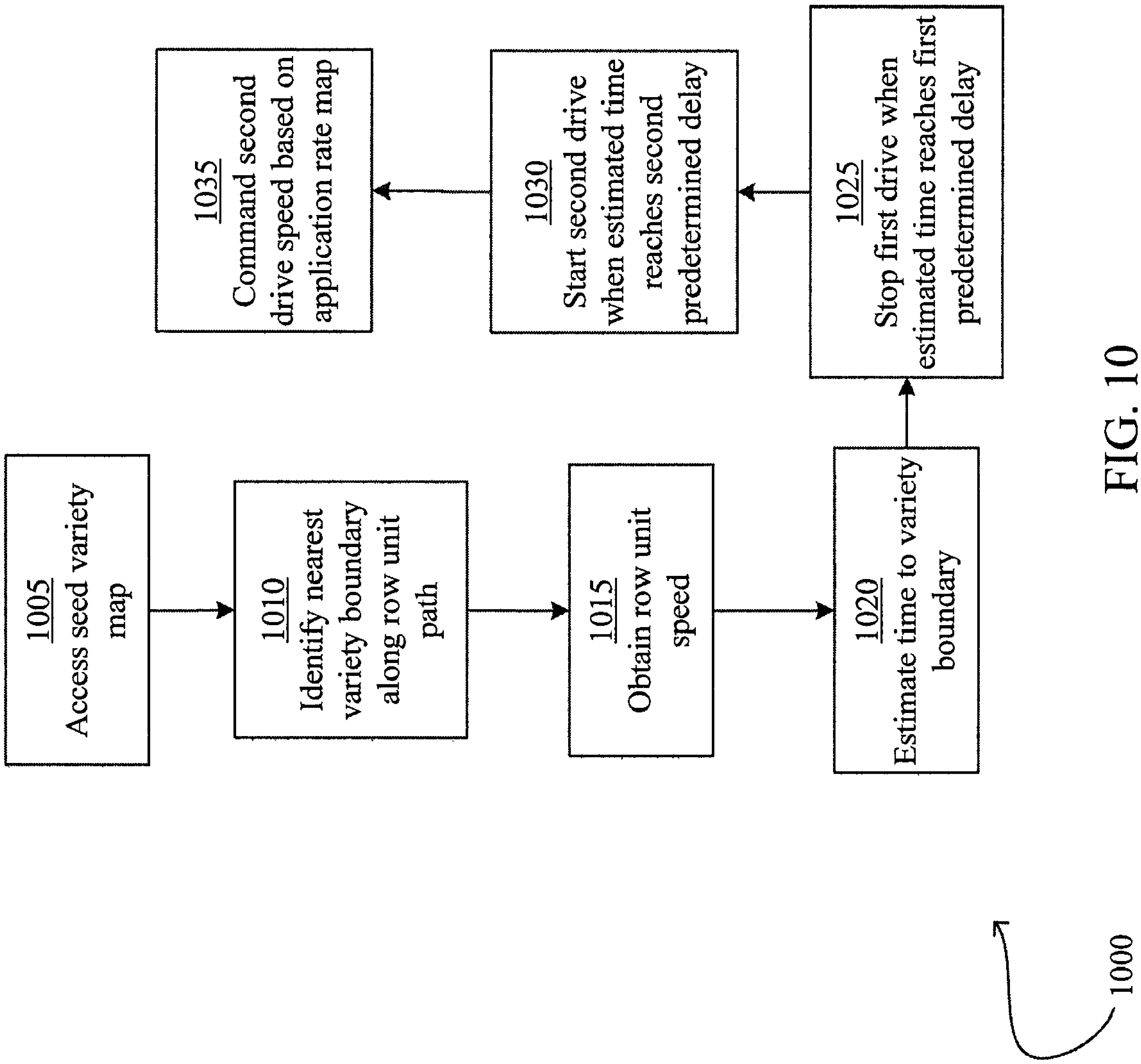

1005
Access seed variety map
1010
Identify nearest variety boundary along row unit path
1015
Obtain row unit speed
1020
Estimate time to variety boundary
1025
Stop first drive when estimated time reaches first predetermined delay
1030
Start second drive when estimated time reaches second predetermined delay
1035
Command second drive speed based on application rate map
1000

FIG. 10

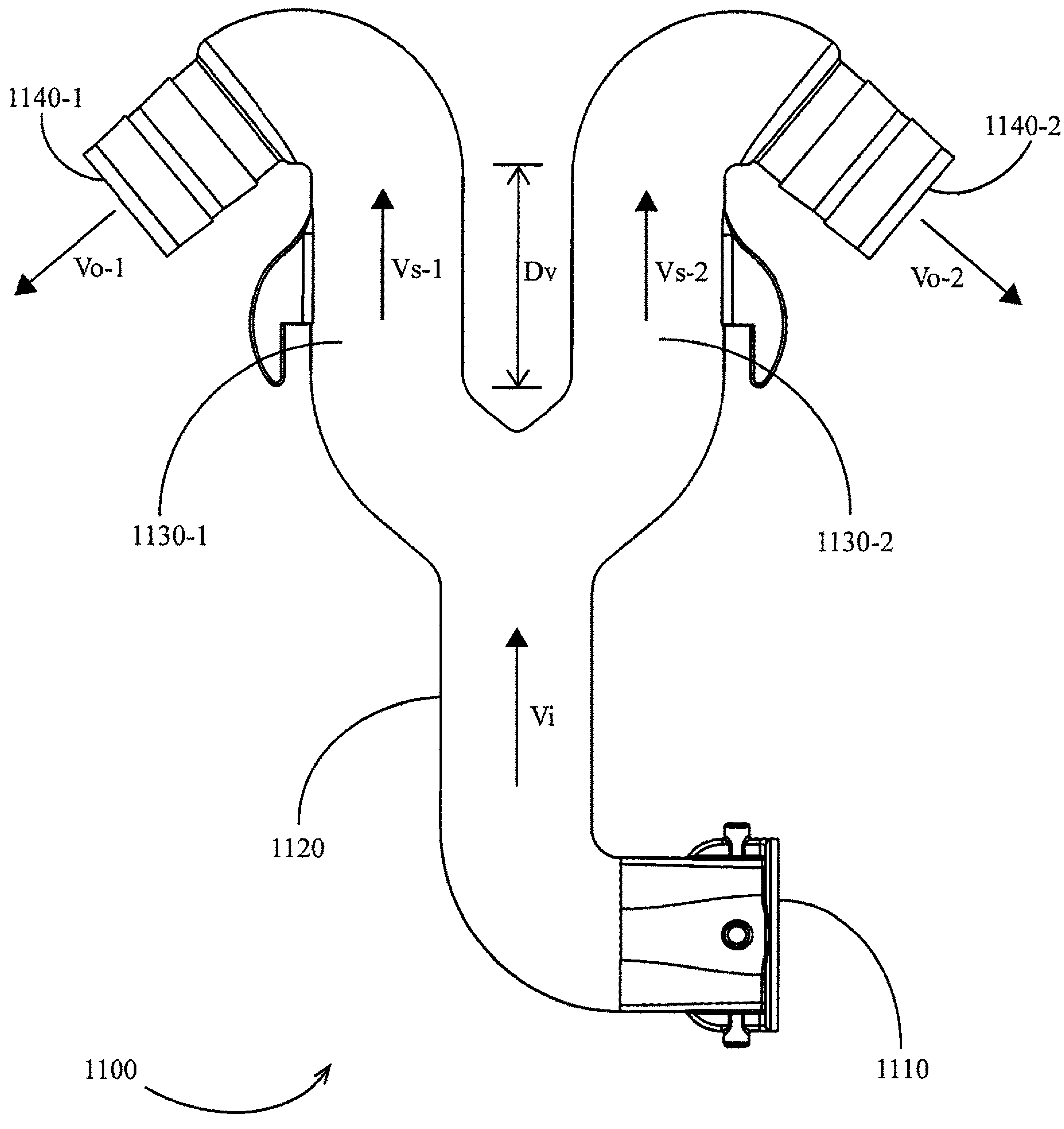


FIG. 11

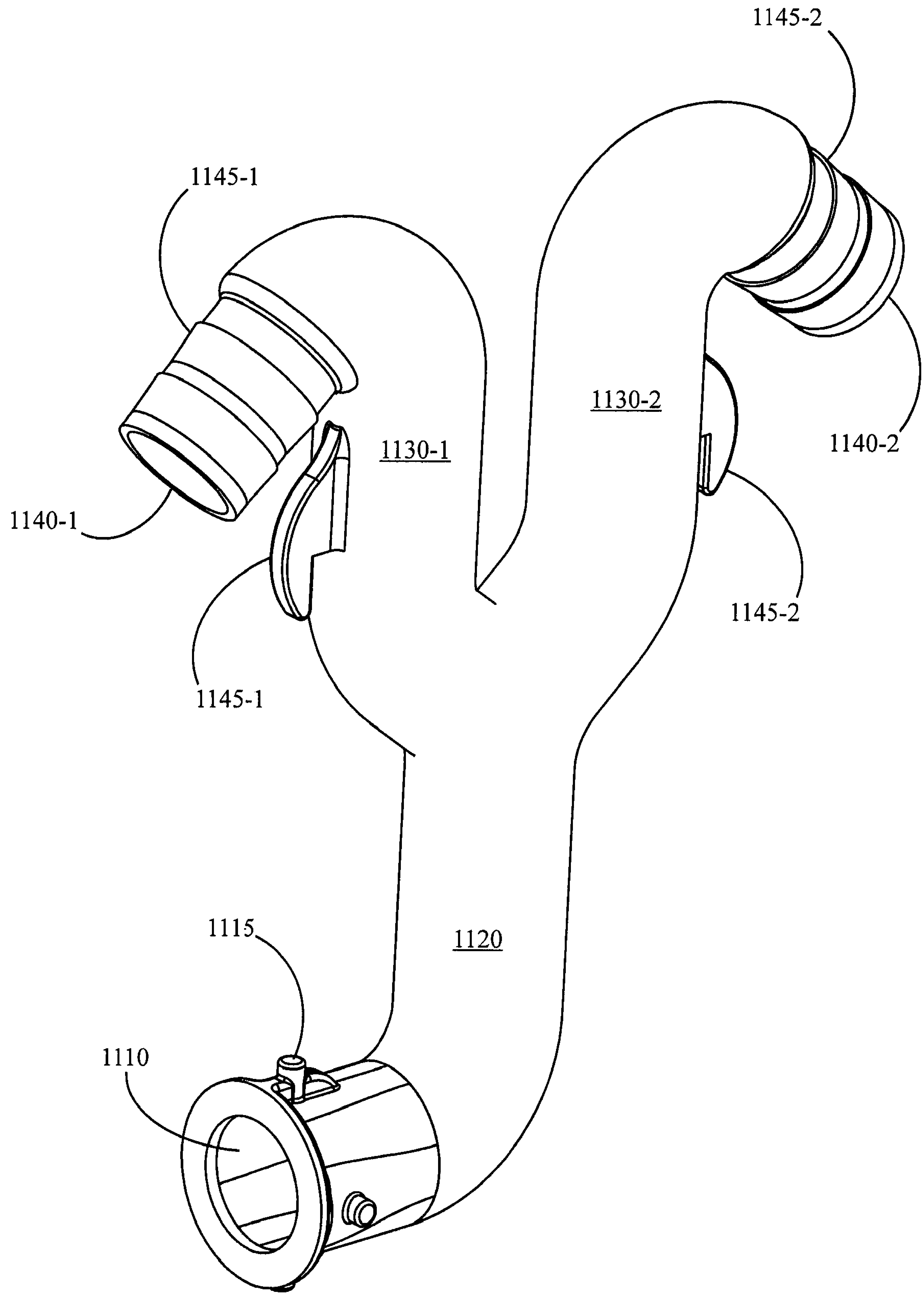

1145-2
1145-1
1130-2
1130-1
1140-2
1140-1
1145-2
1145-1
1115
1120
1110

FIG. 12

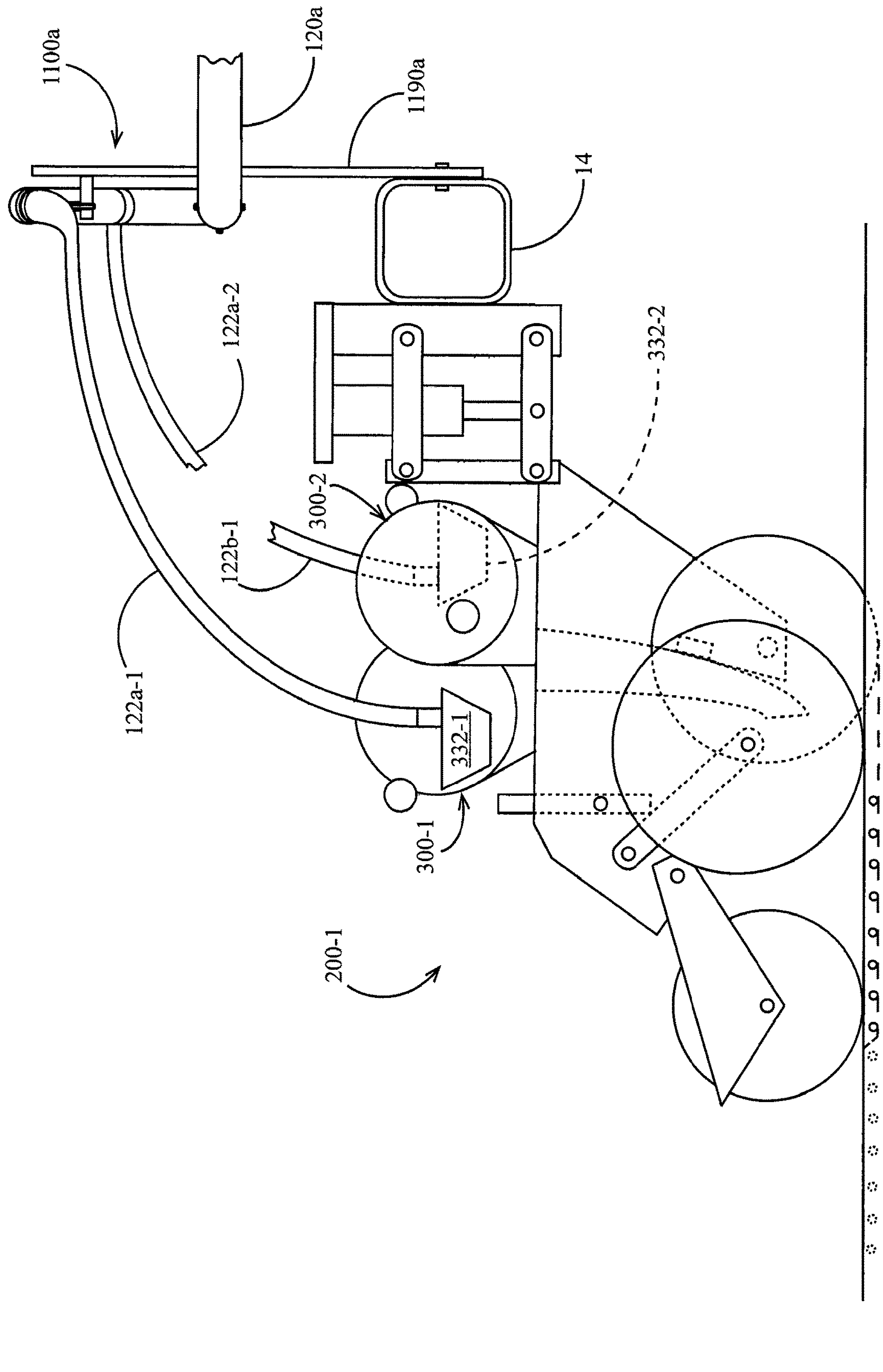

1100a
120a
1190a
14
122a-2
332-2
300-2
122b-1
122a-1
332-1
300-1
200-1

FIG. 13

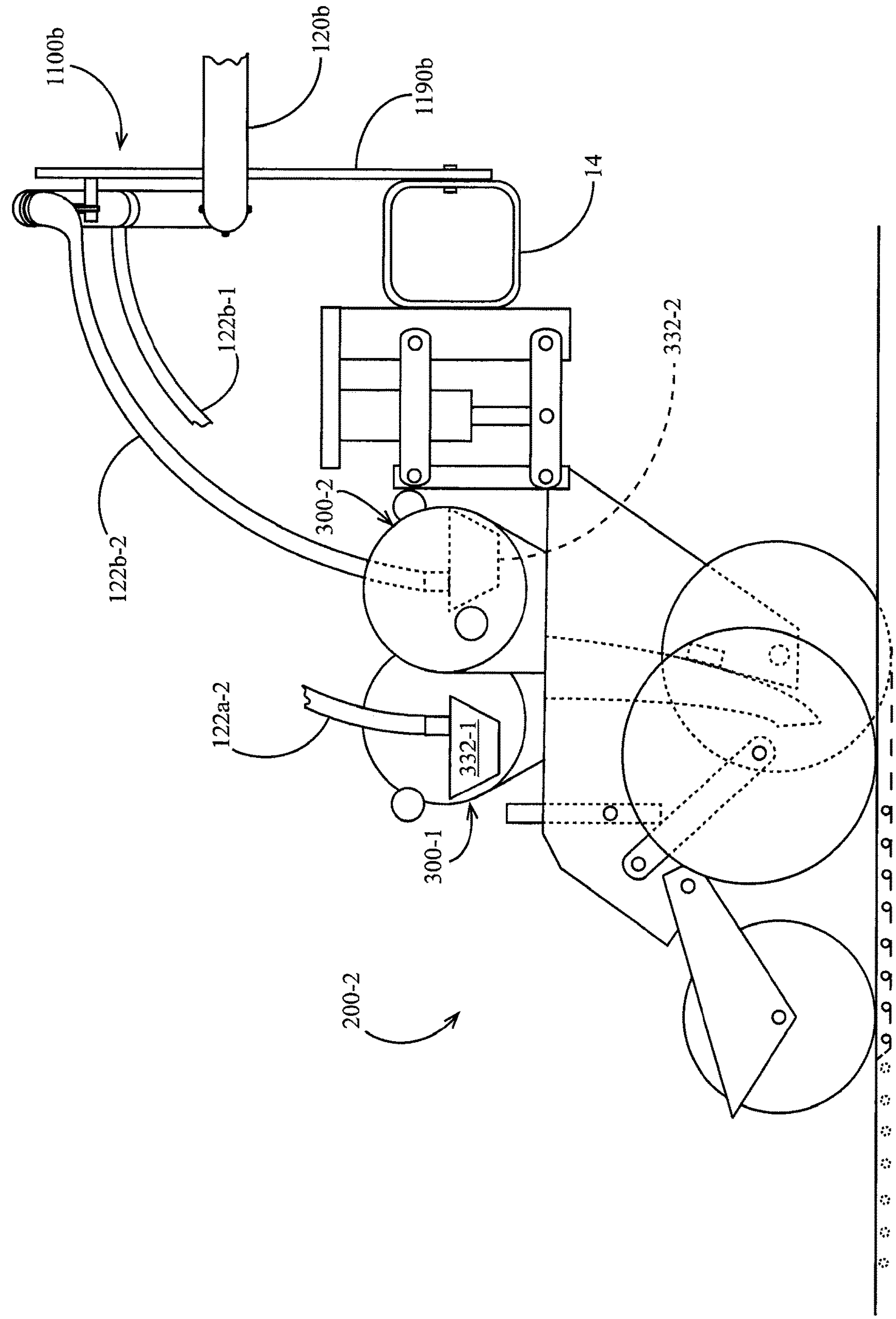

1100b
120b
1190b
14
122b-1
332-2
122b-2
300-2
122a-2
332-1
300-1
200-2

FIG. 14

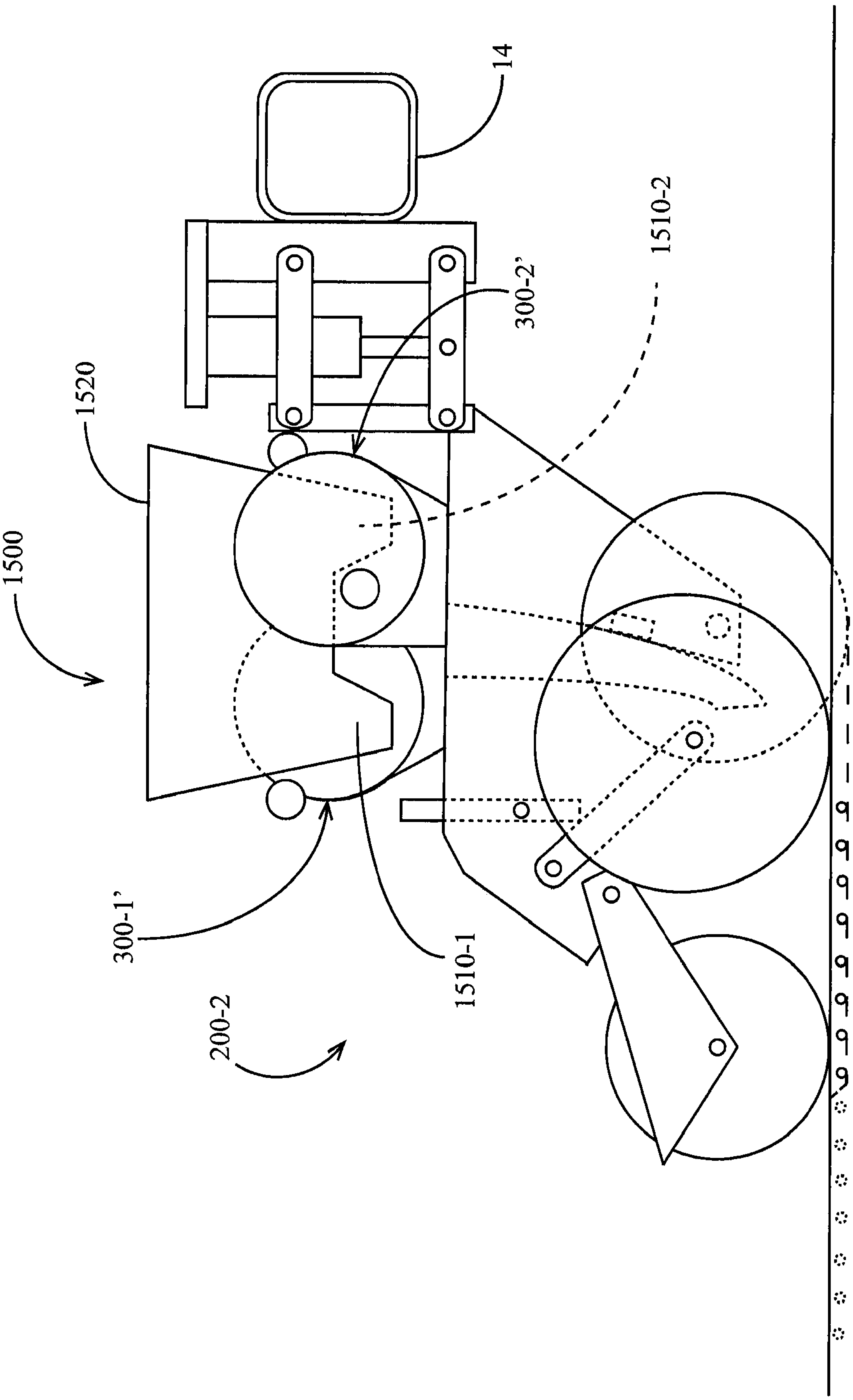


FIG. 15

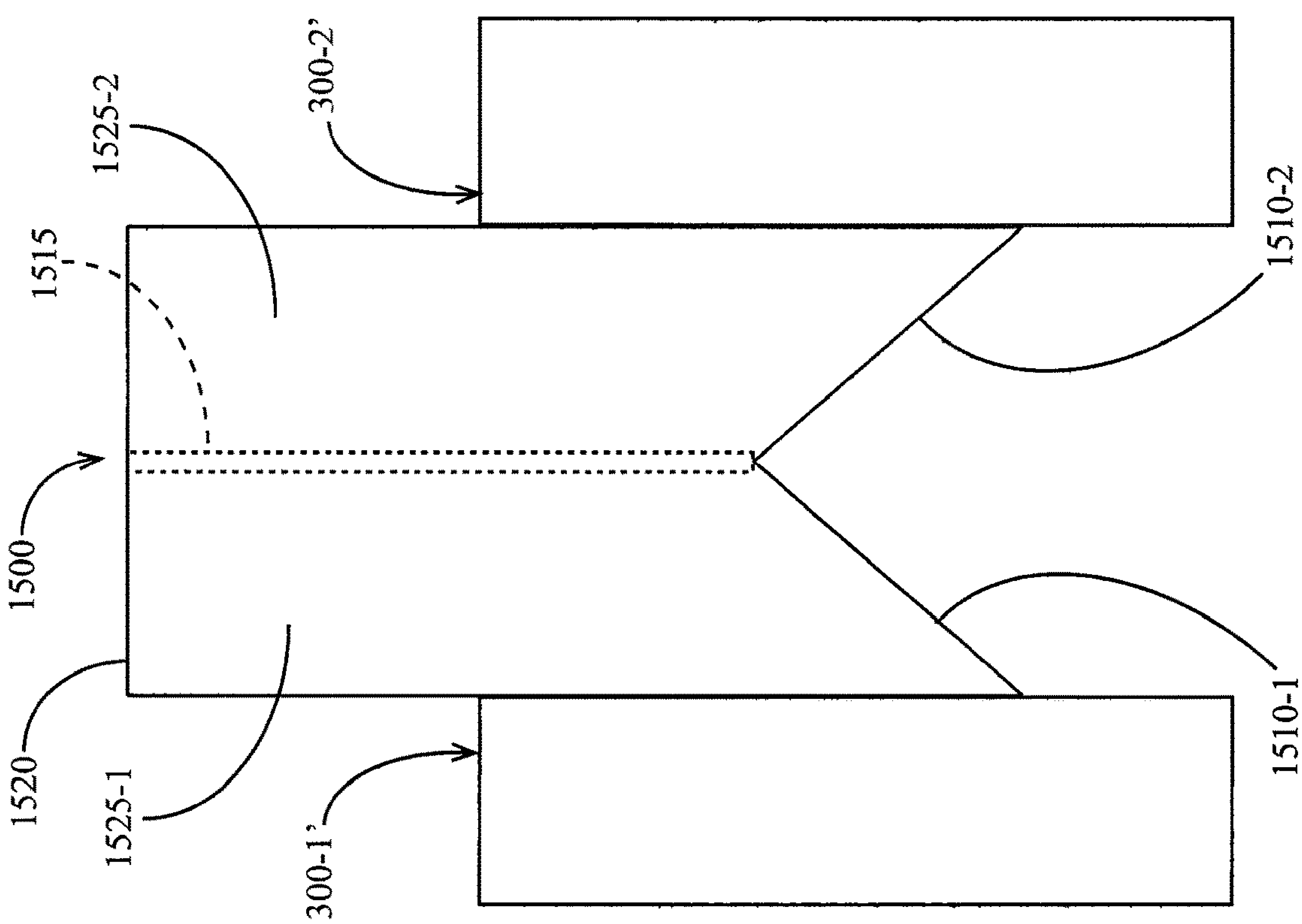


FIG. 16A

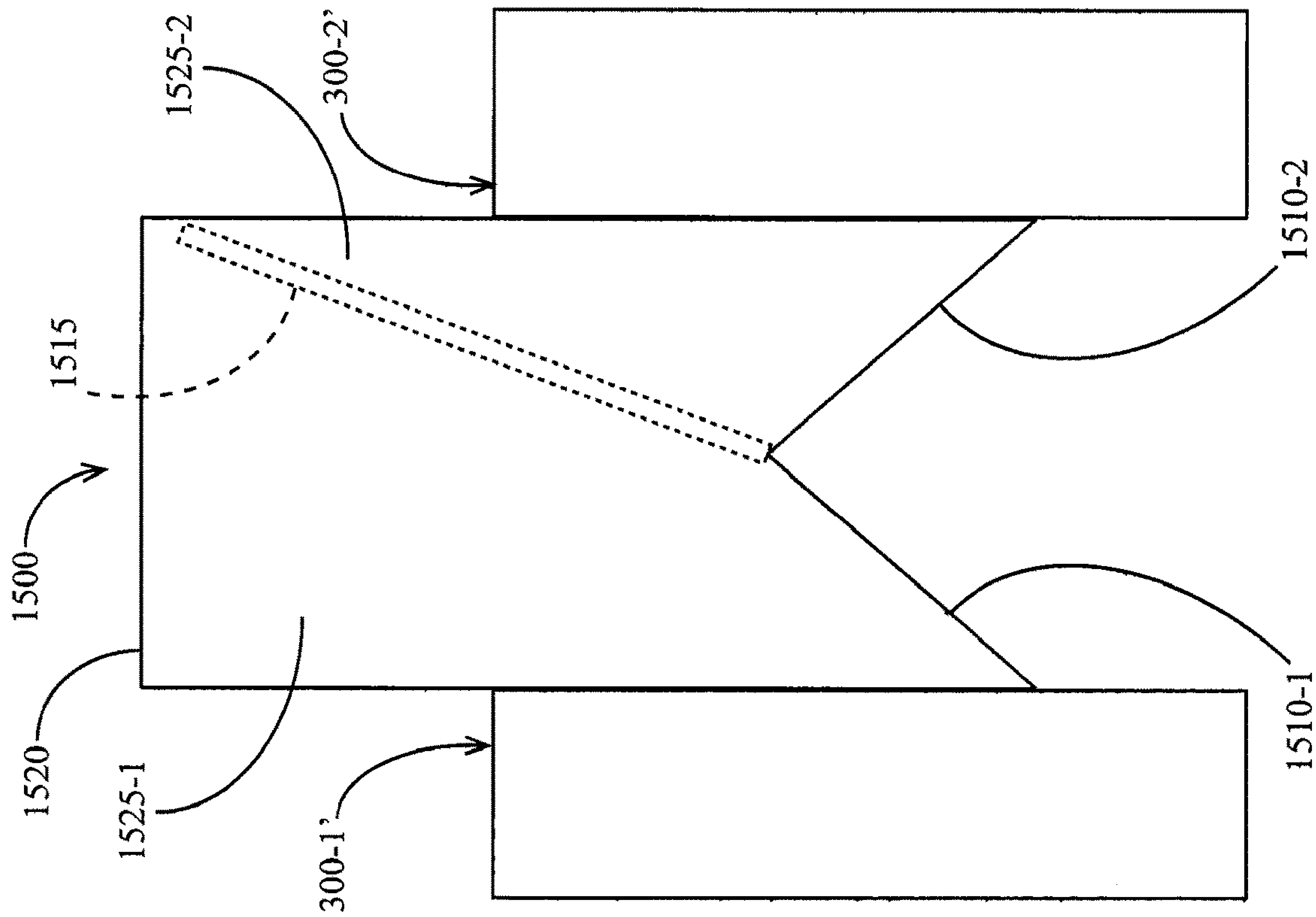


FIG. 16B

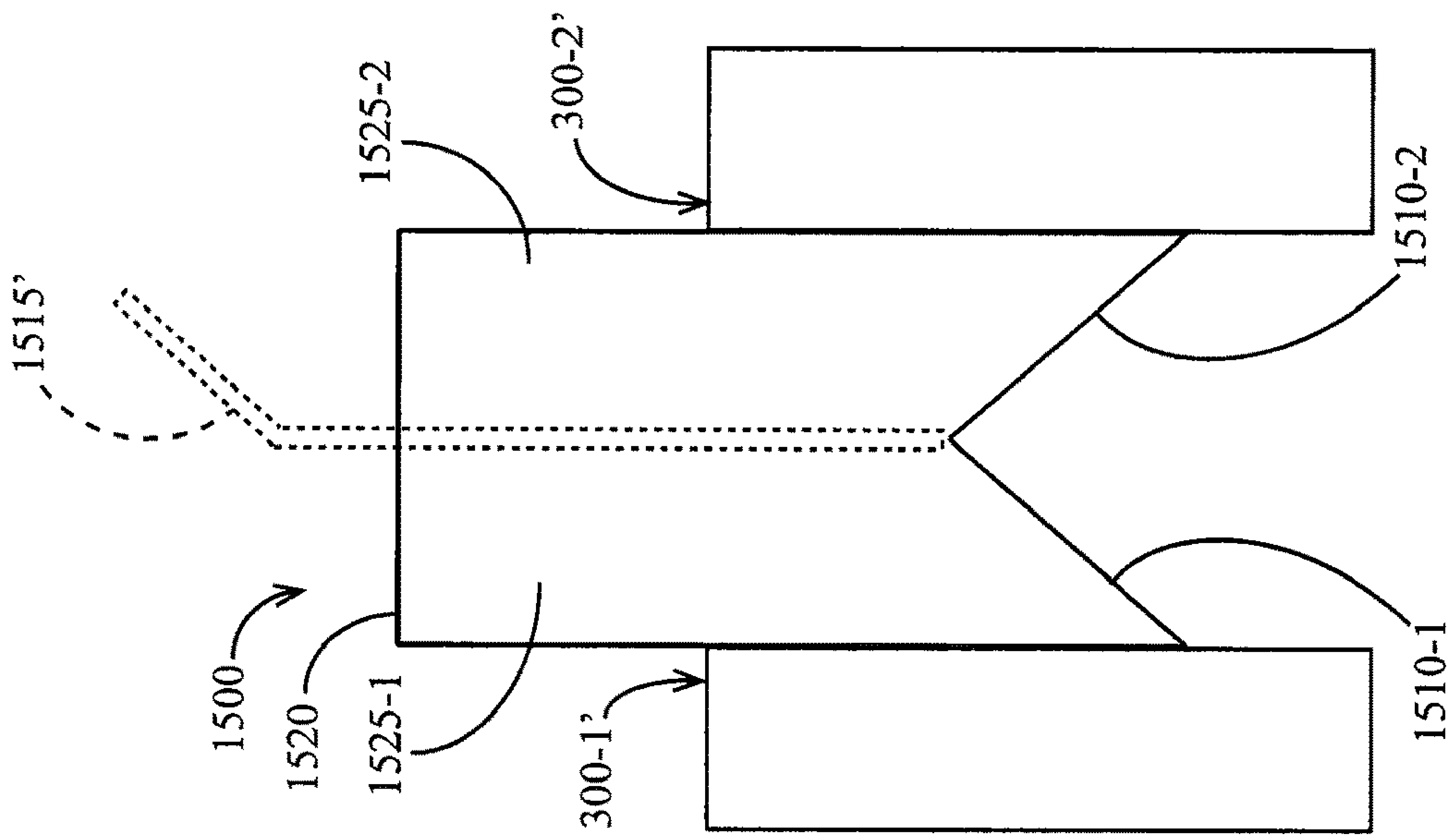


FIG. 16E

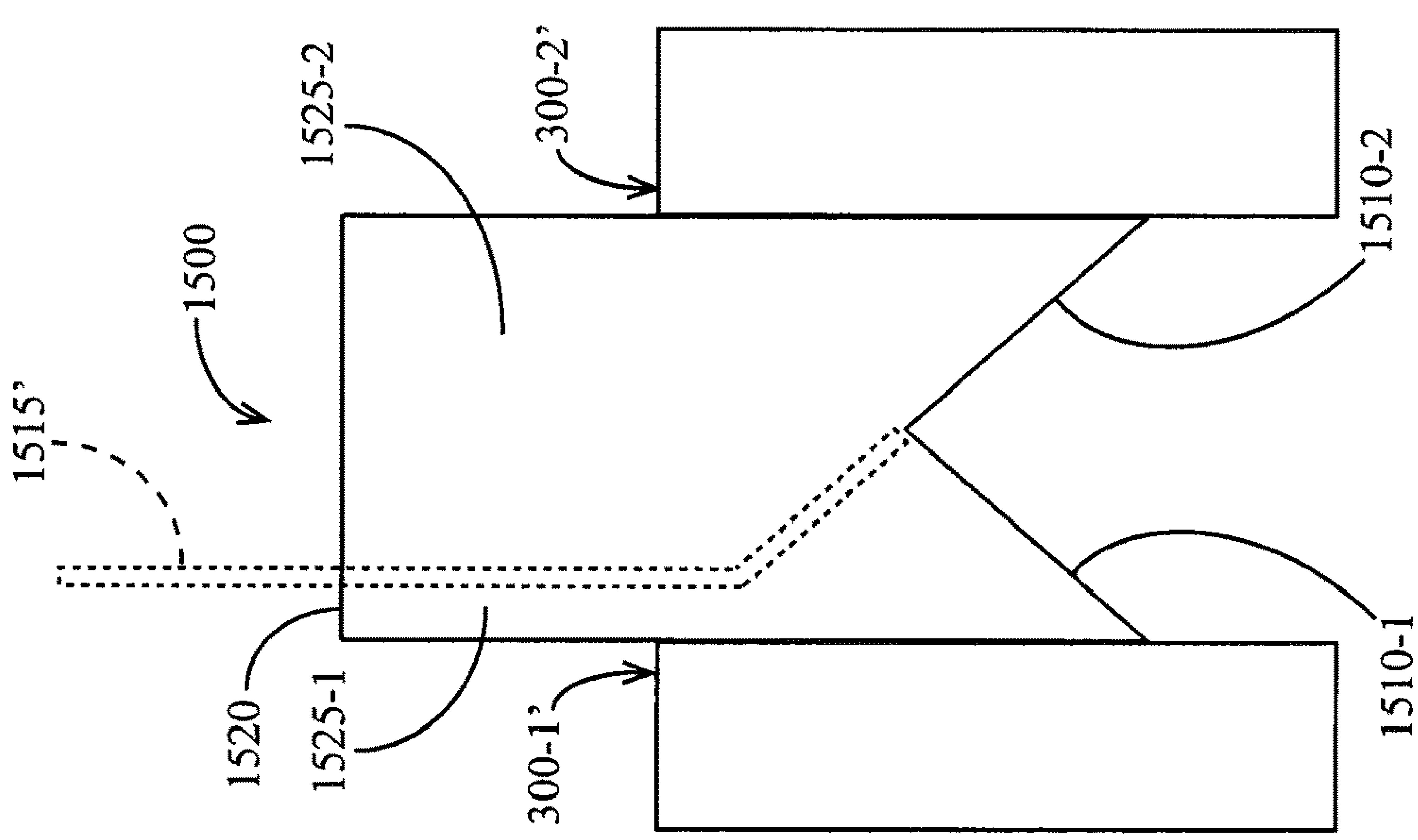


FIG. 16D

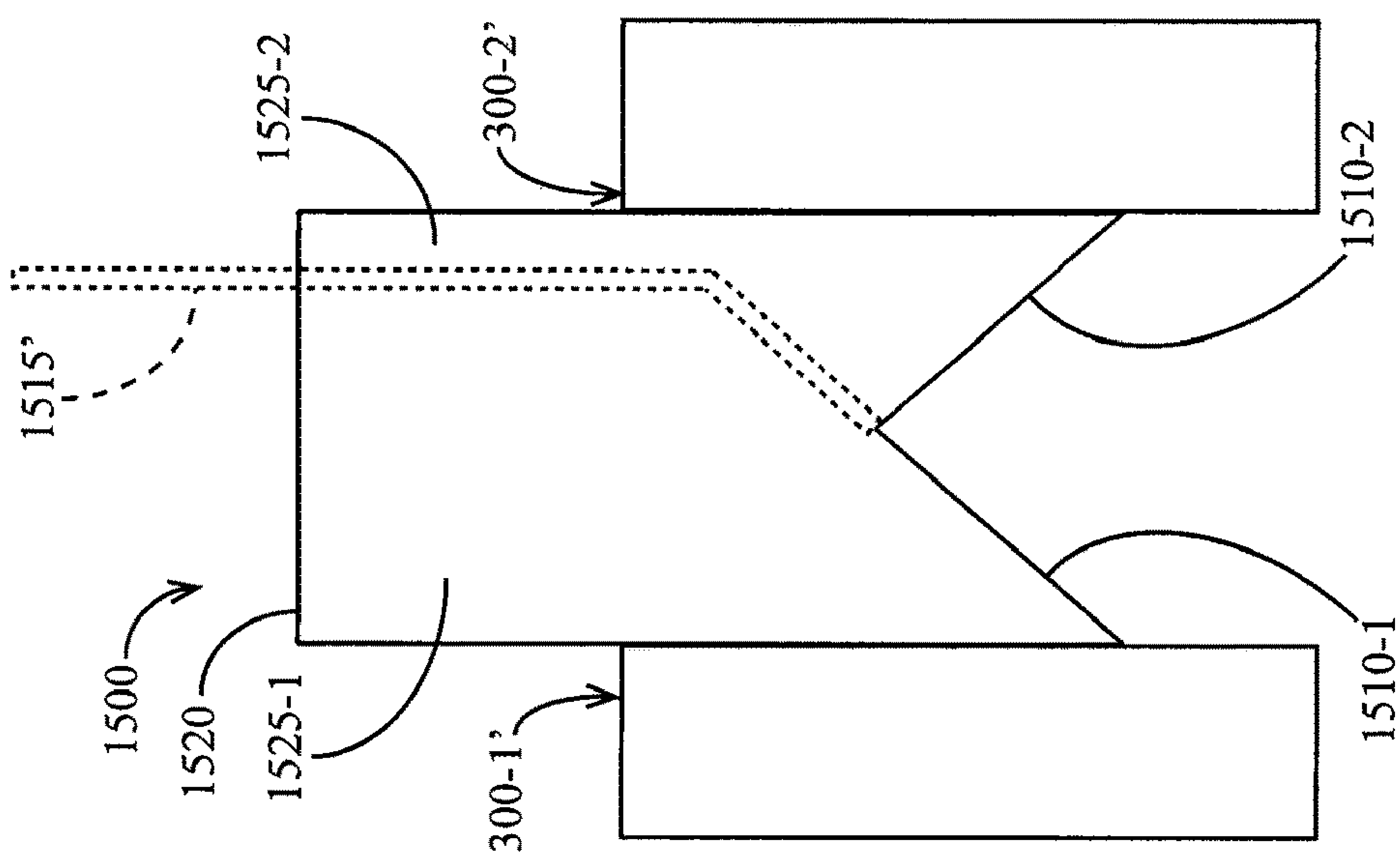


FIG. 16C

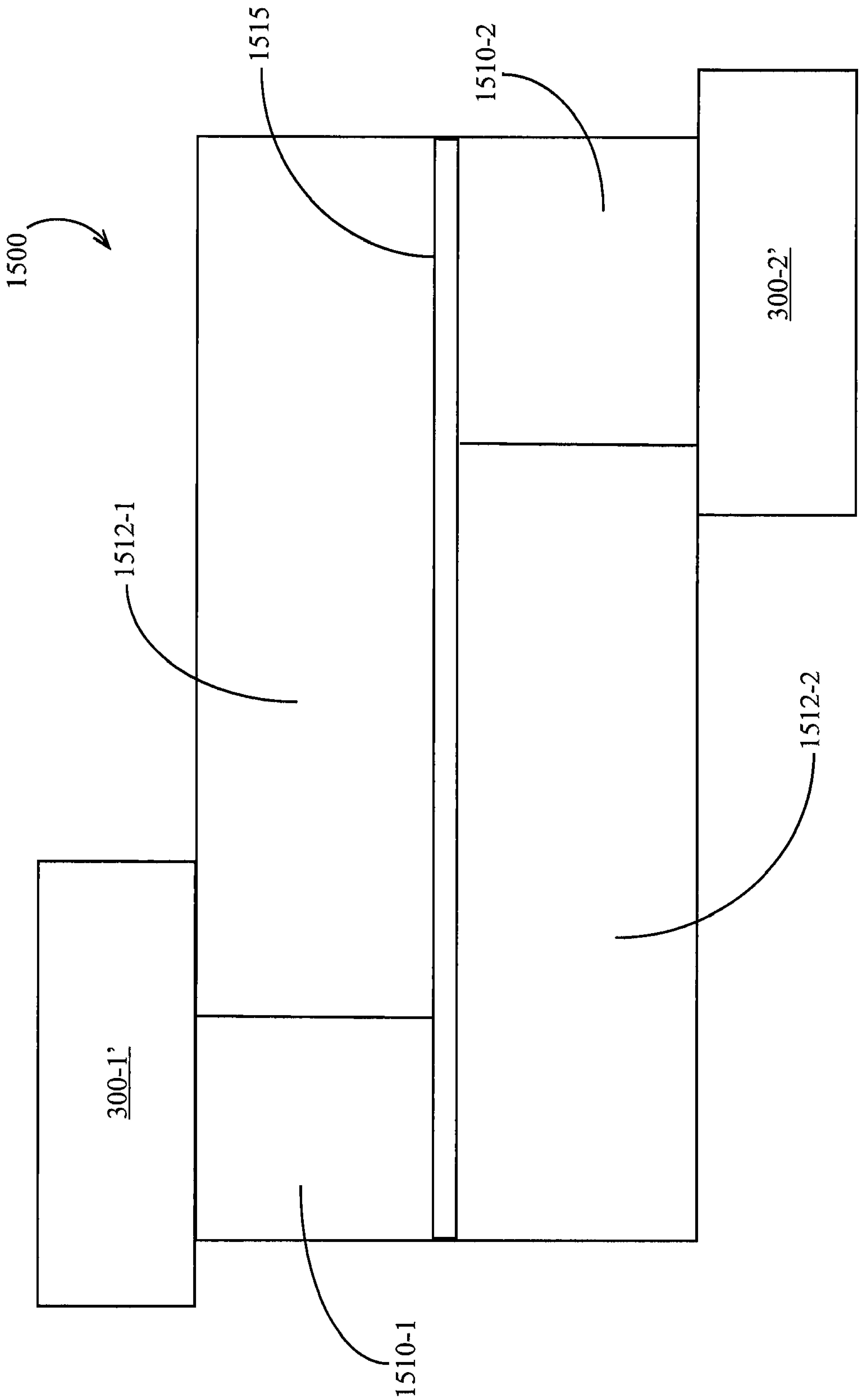


FIG. 17

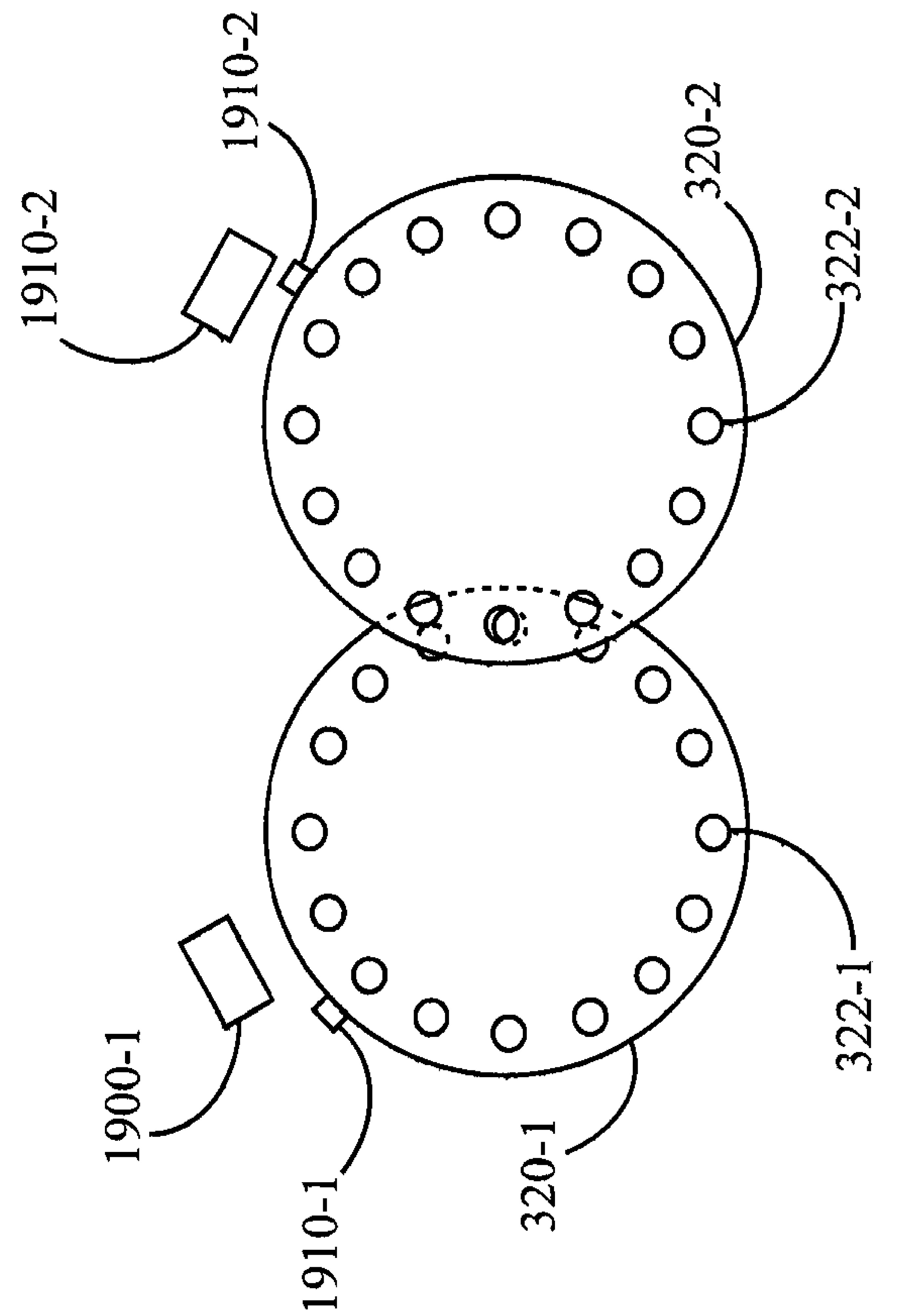

1910-2
1910-2
320-2
322-2
1900-1
1910-1
320-1
322-1

FIG. 19

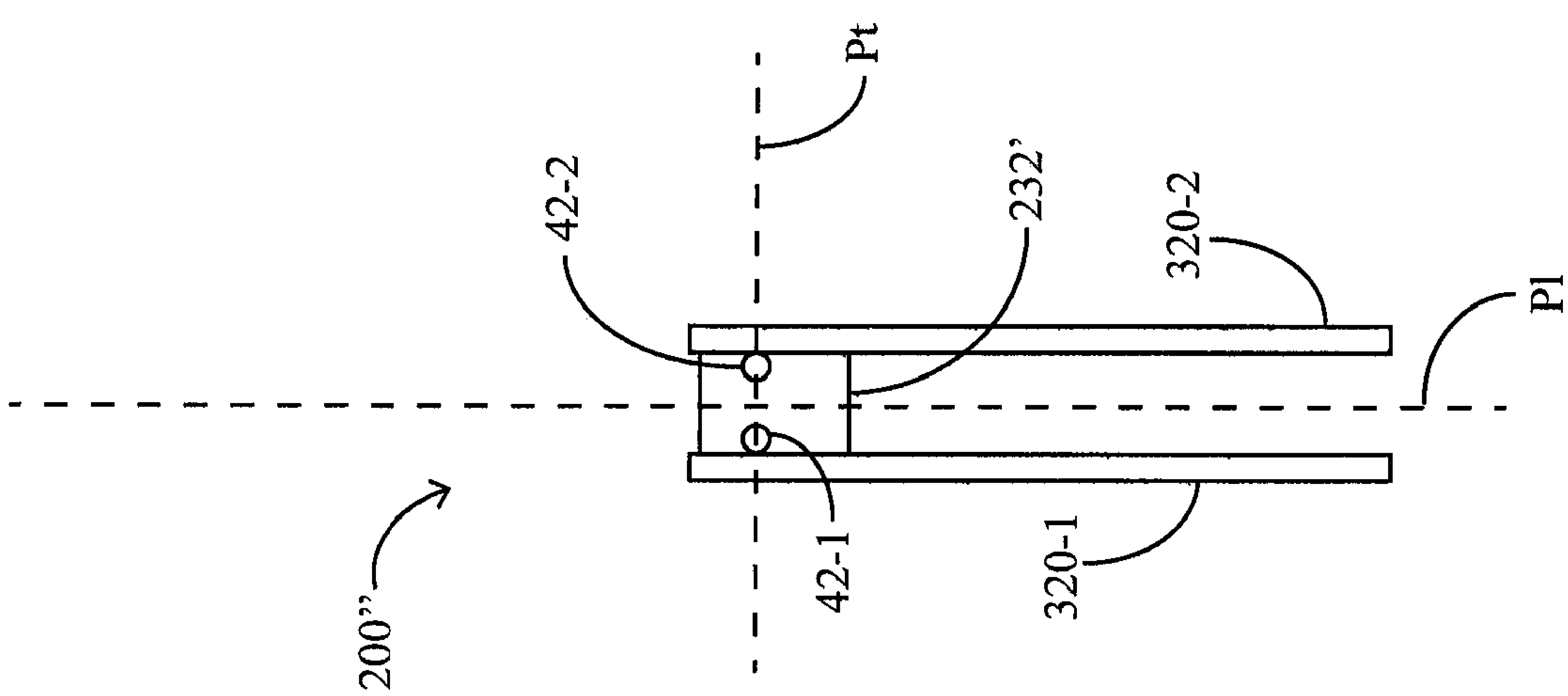

Pt
42-2
232'
320-2
Pl
200"
42-1
320-1

FIG. 18

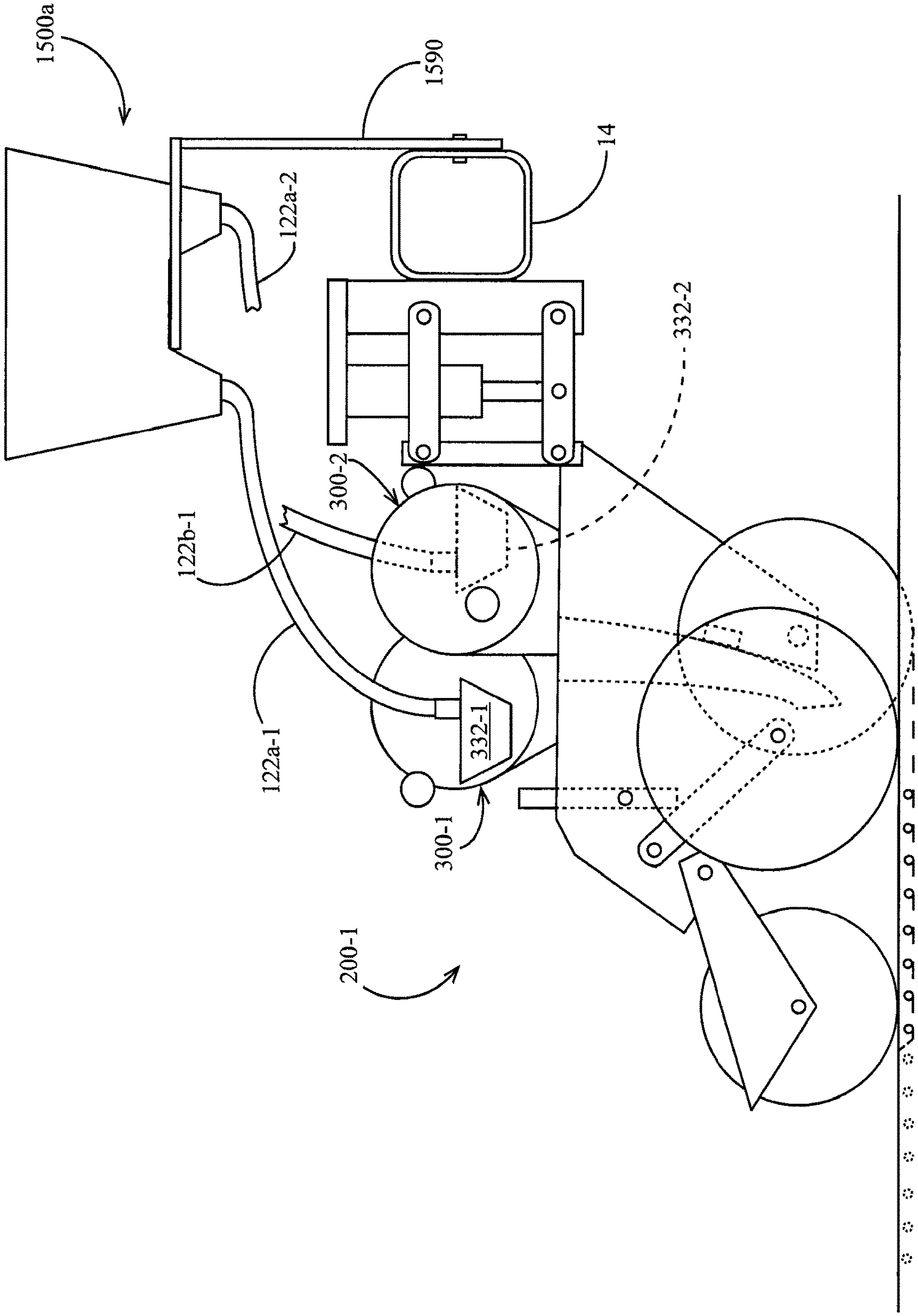
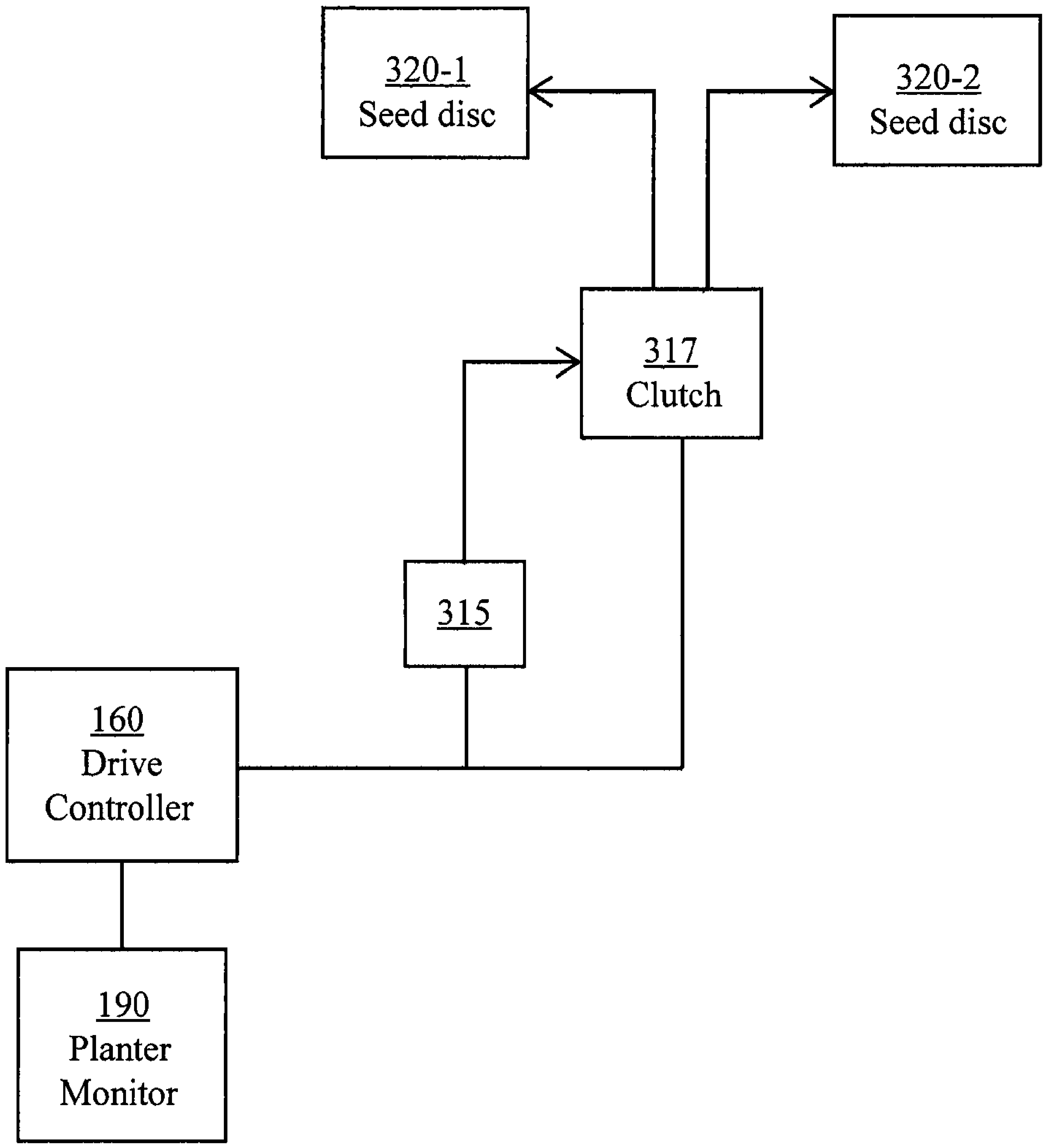


FIG. 20



320-1
Seed disc
320-2
Seed disc
317
Clutch
315
160
Drive
Controller
190
Planter
Monitor

FIG. 21

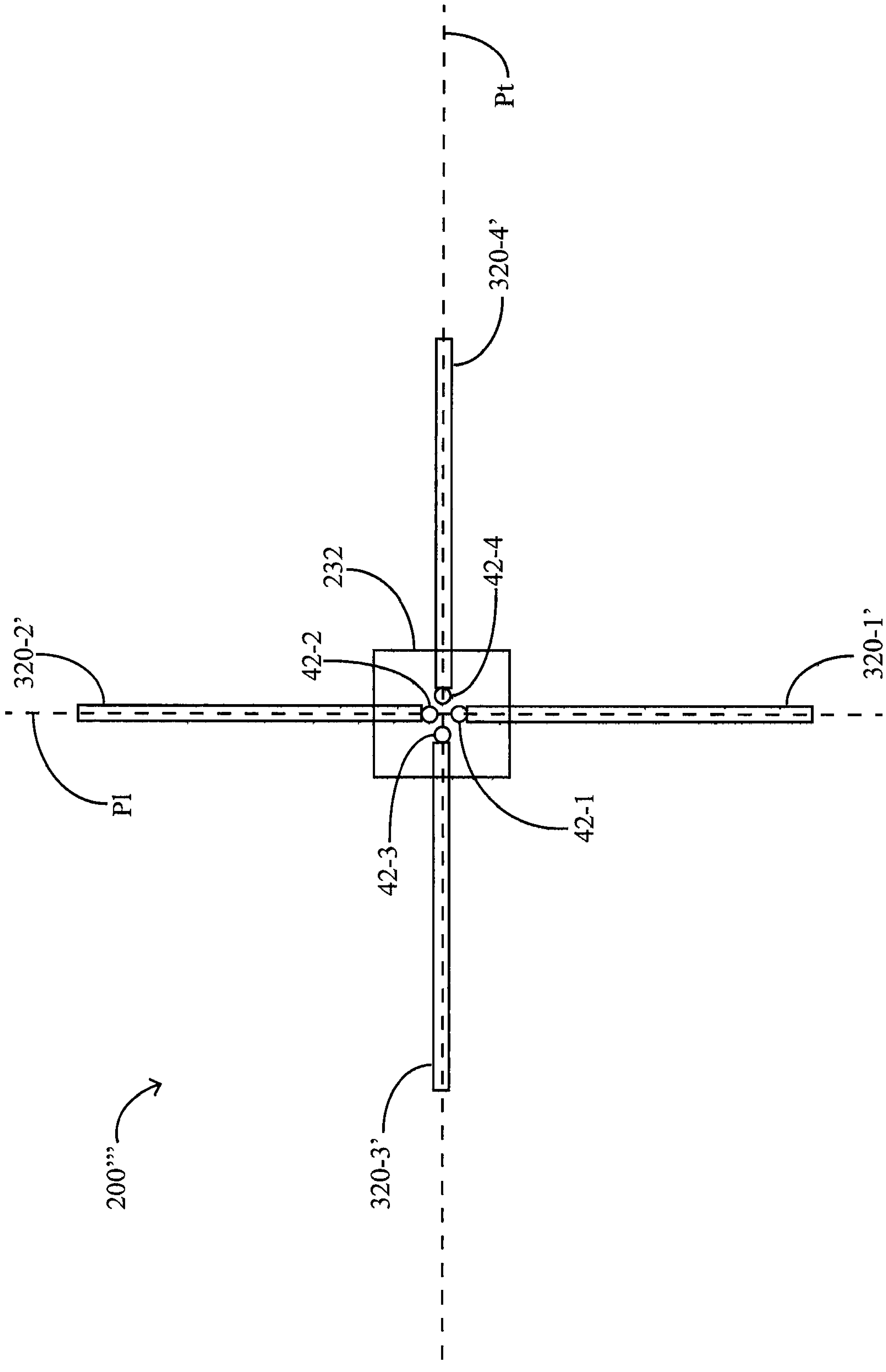


FIG. 22

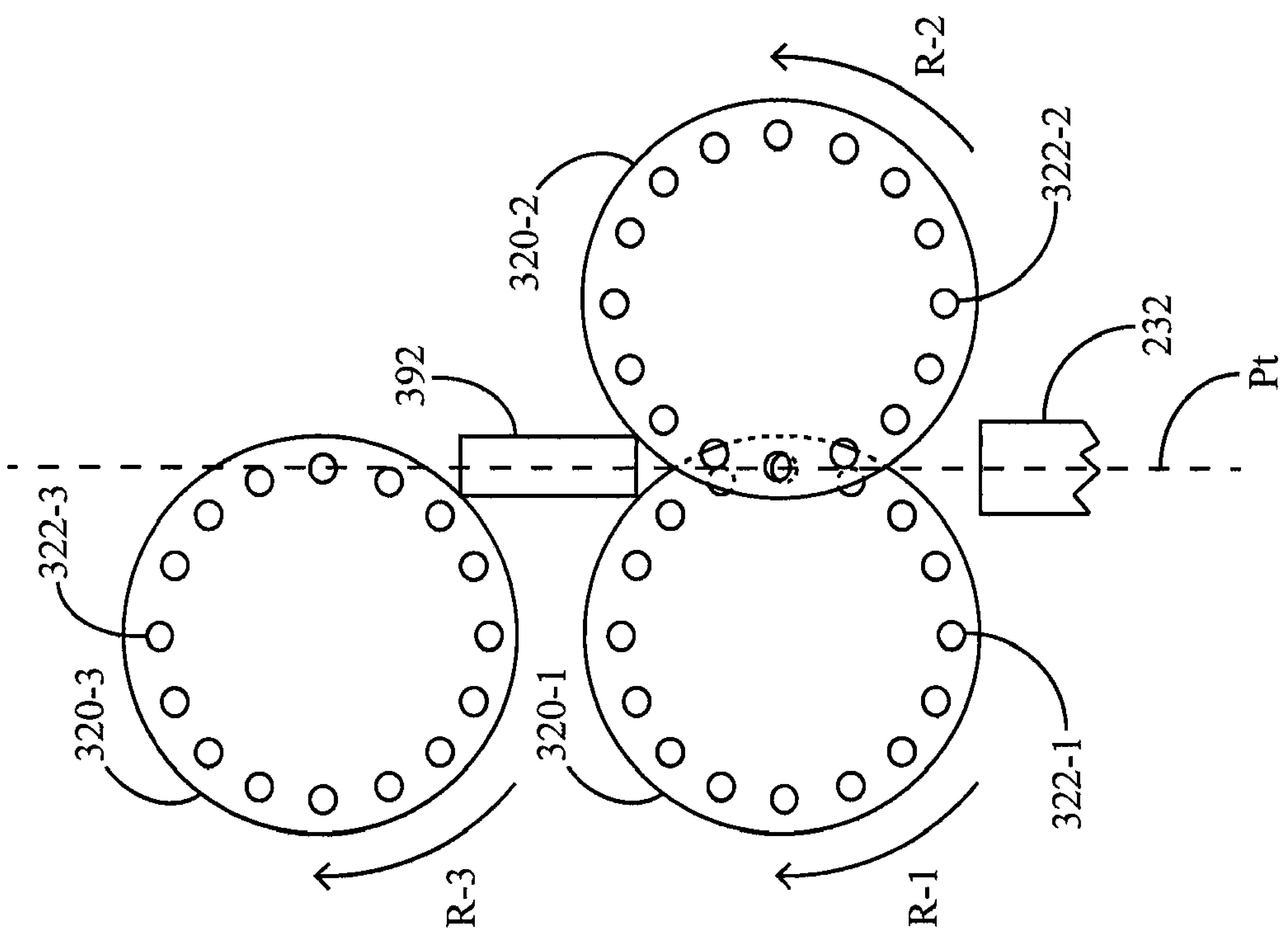


FIG. 23A

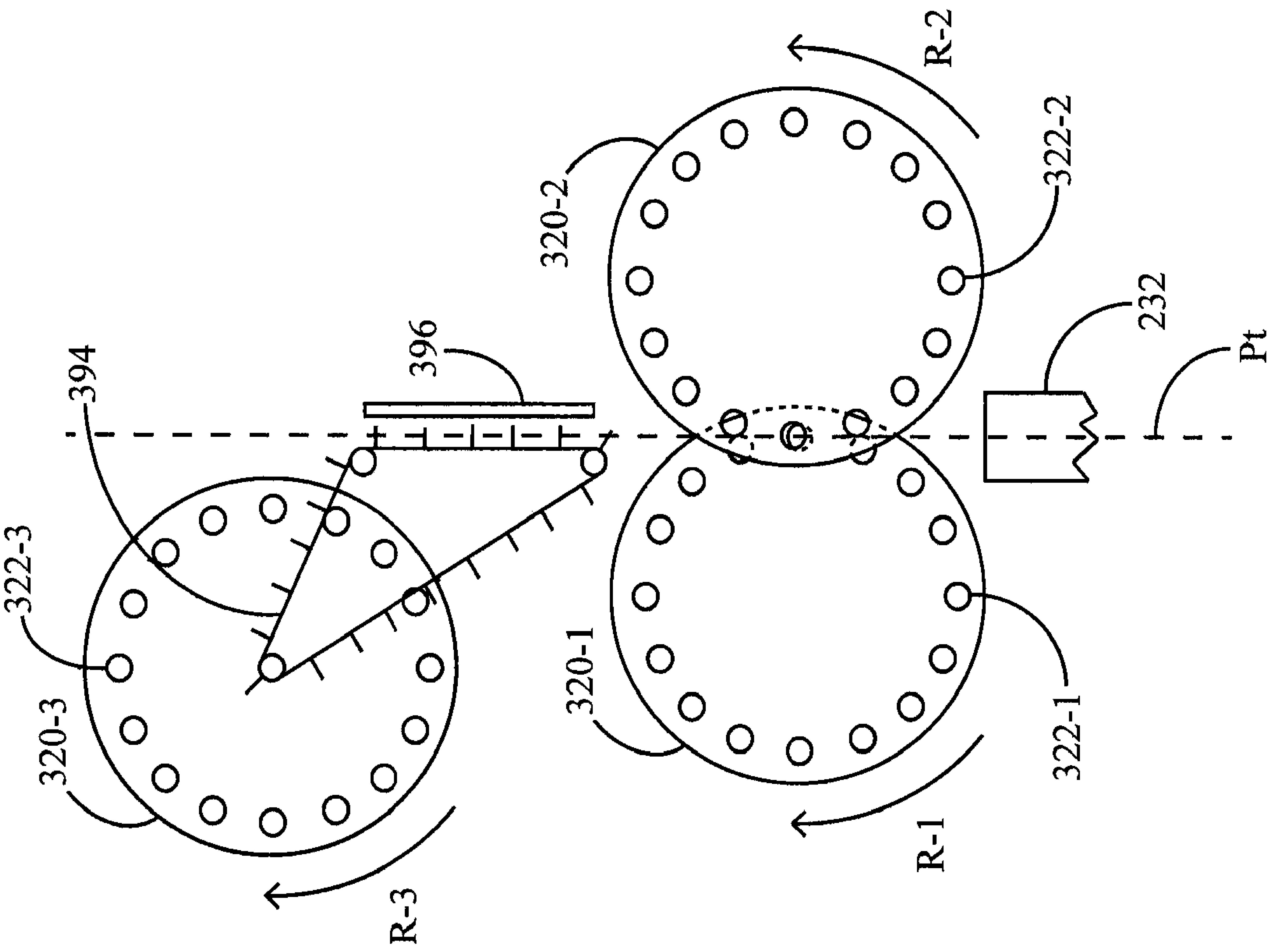


FIG. 23B

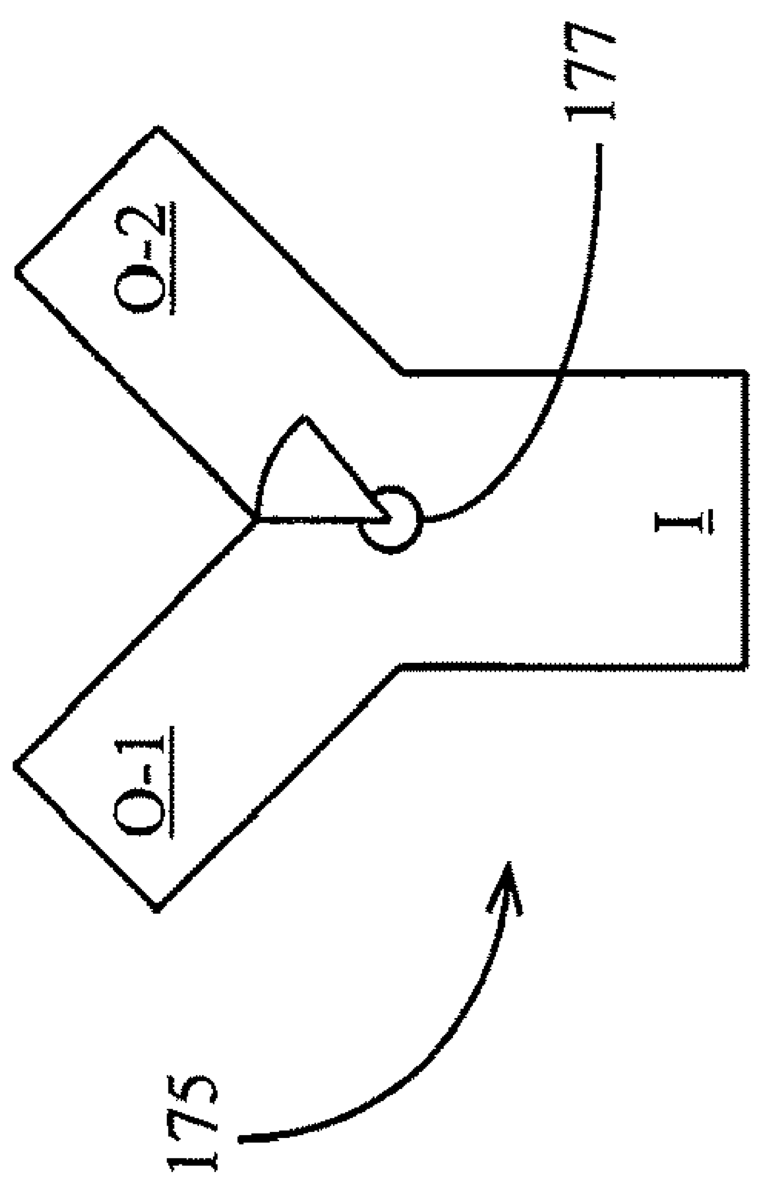


FIG. 25A

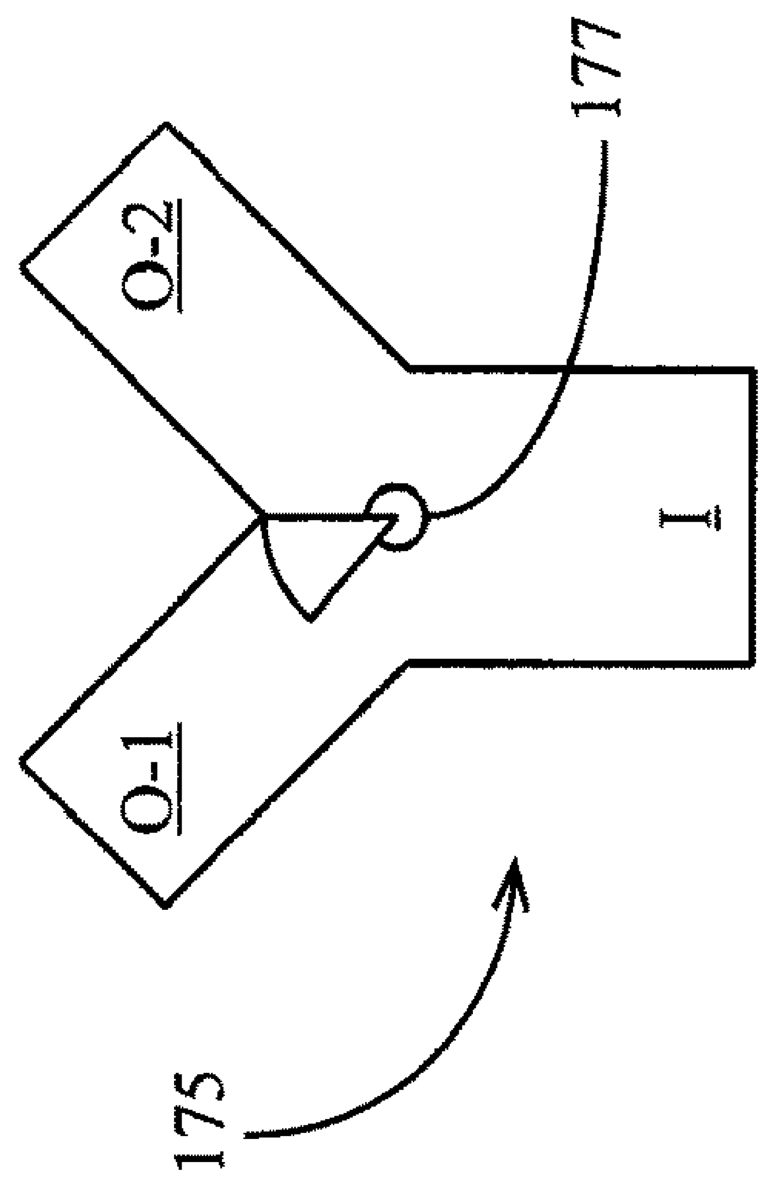


FIG. 25B

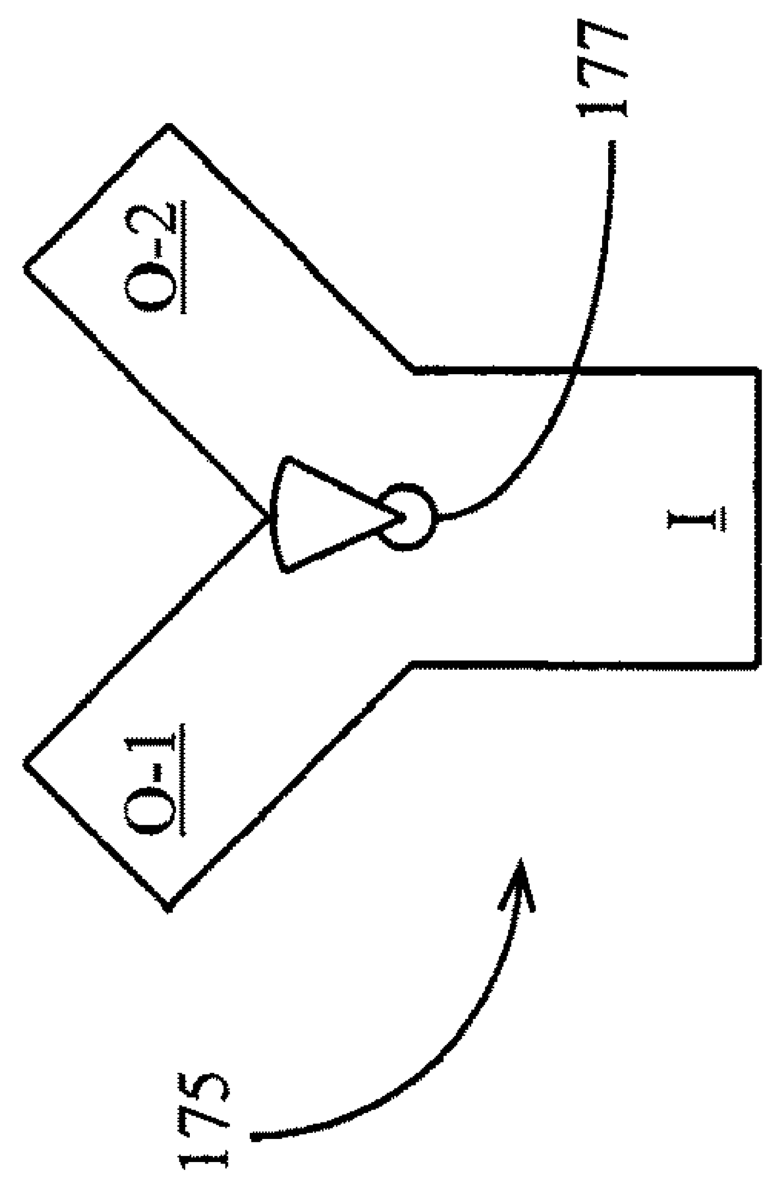


FIG. 25C

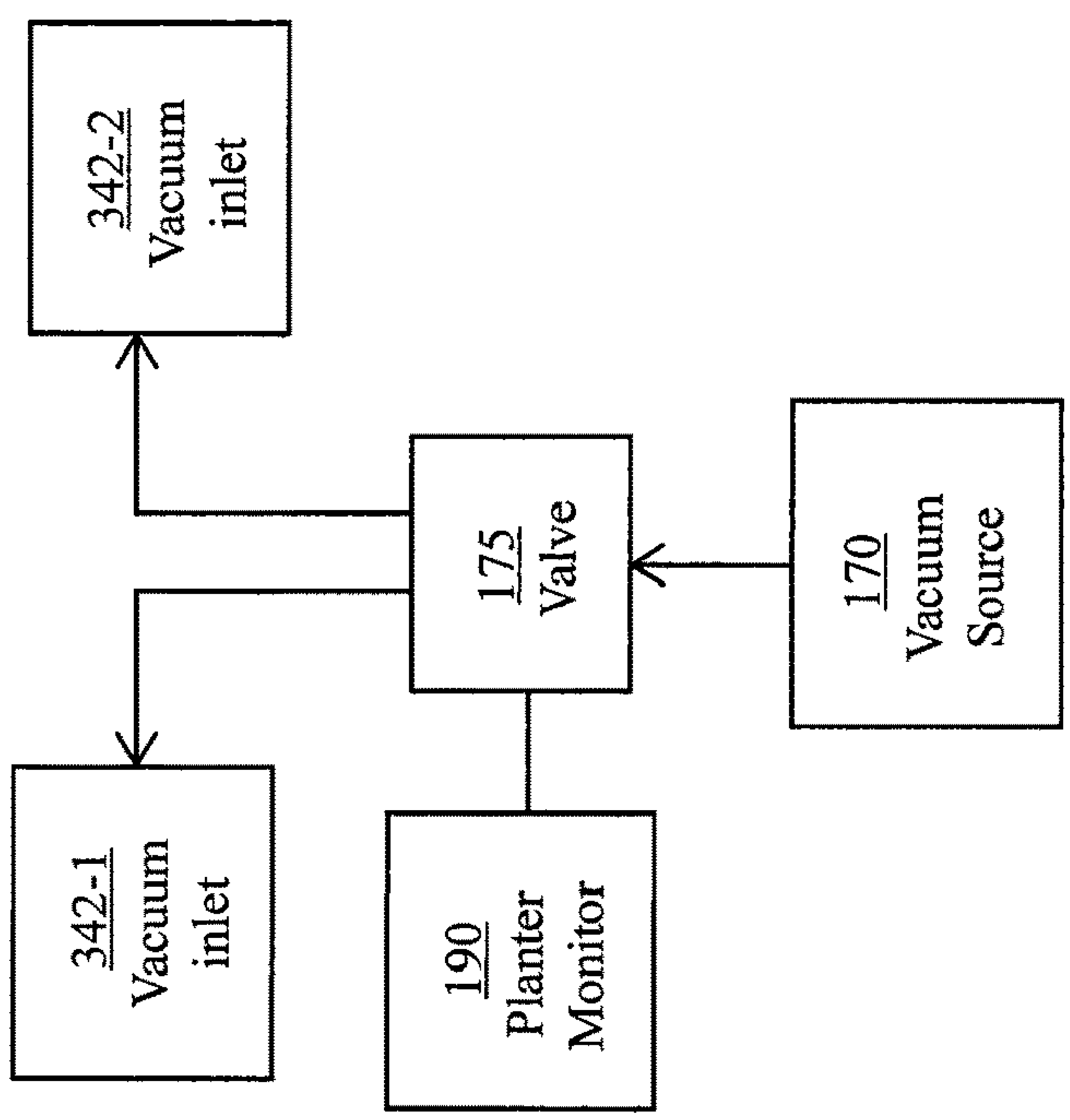


FIG. 24

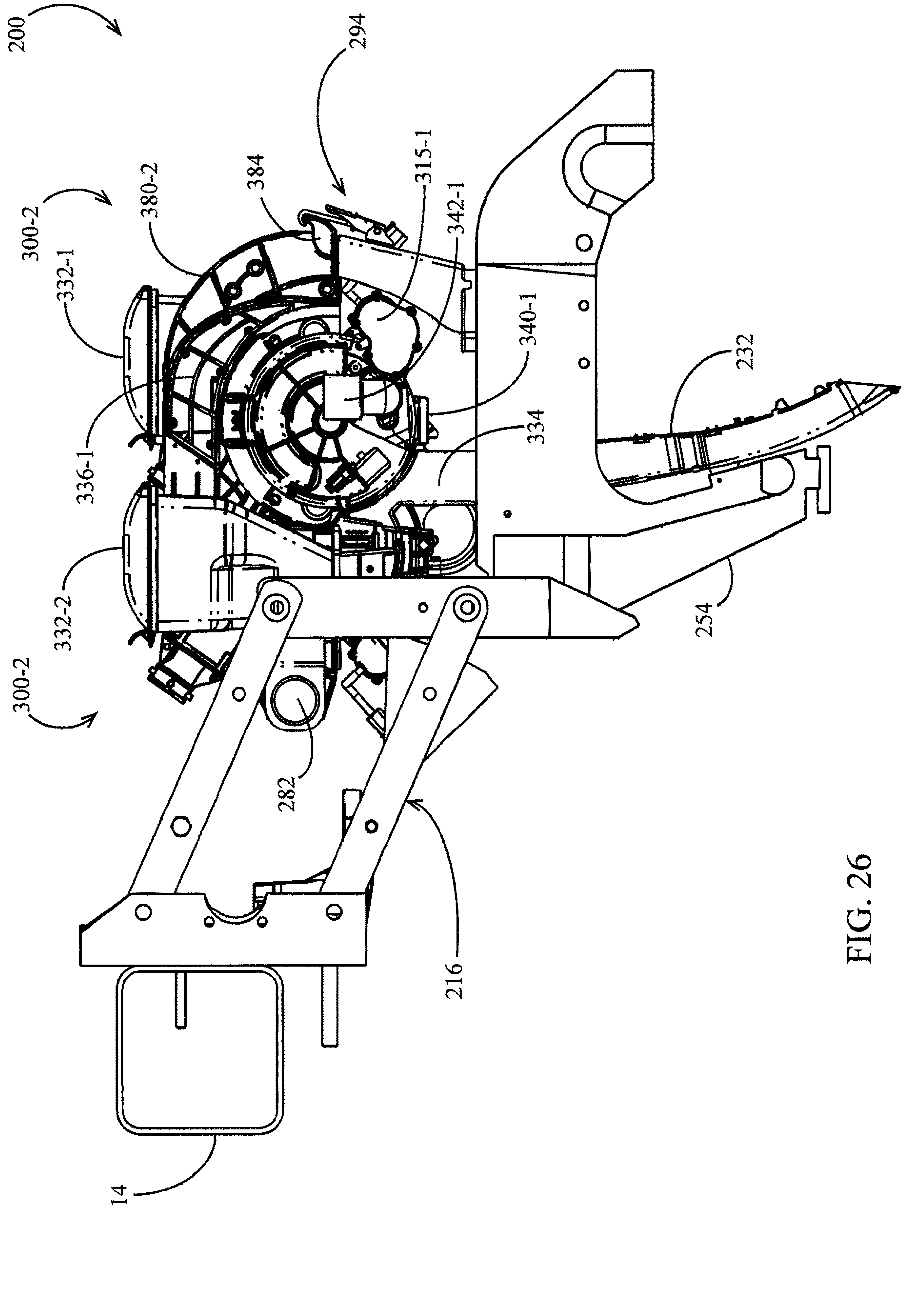

200
294
300-2
332-1
380-2
384
315-1
342-1
340-1
232
334
336-1
332-2
254
300-2
282
216
14

FIG. 26

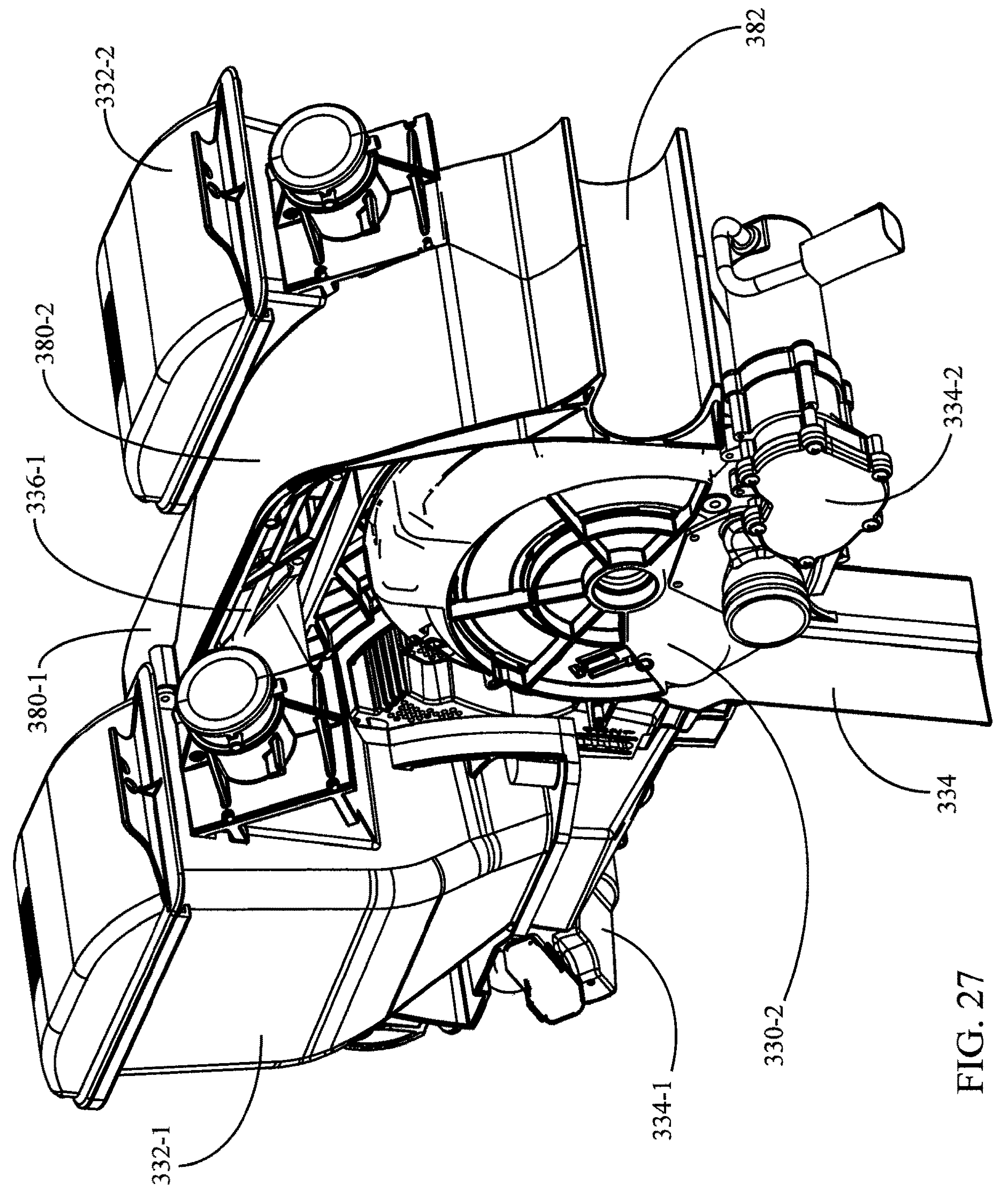


FIG. 27

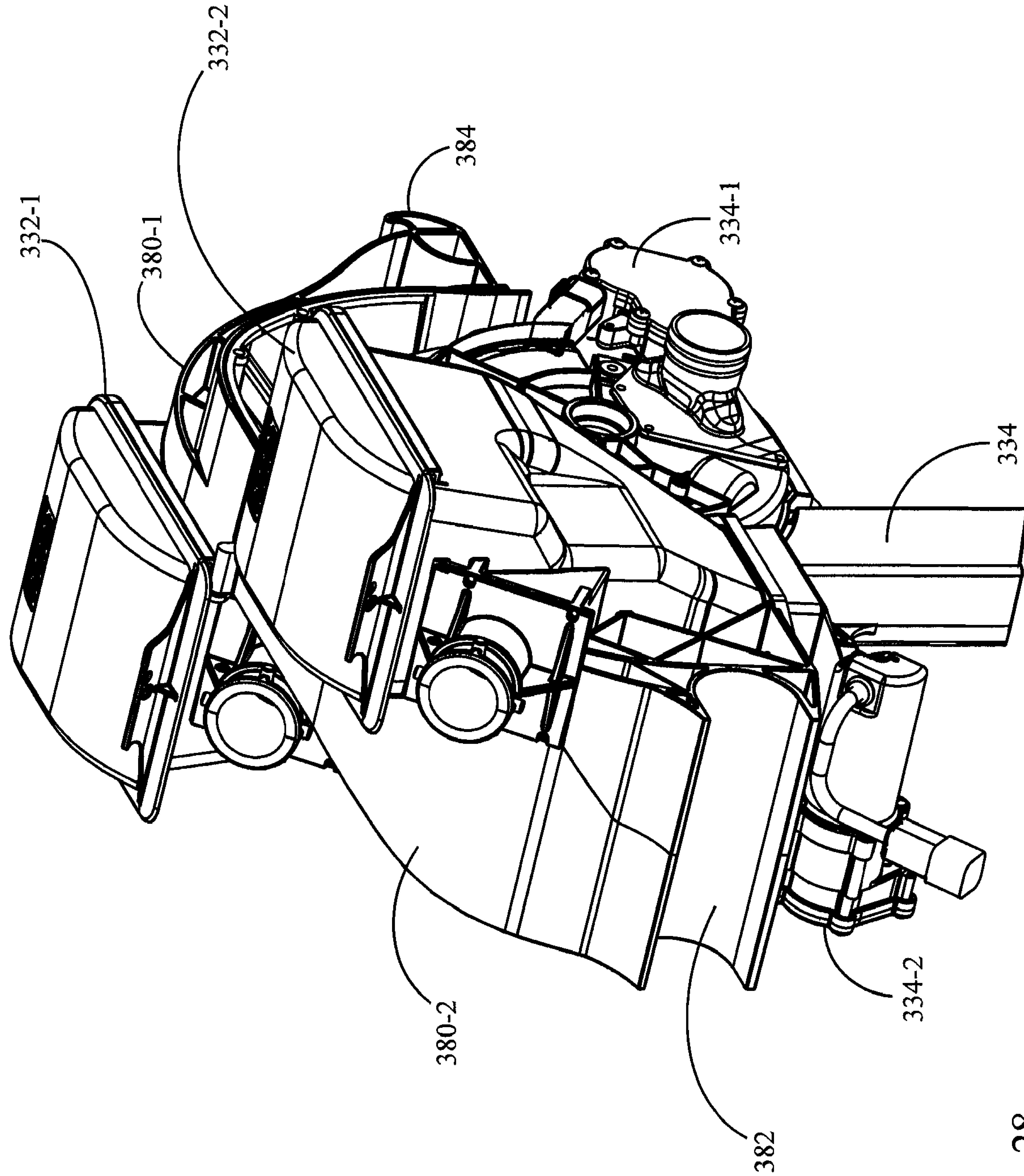


FIG. 28

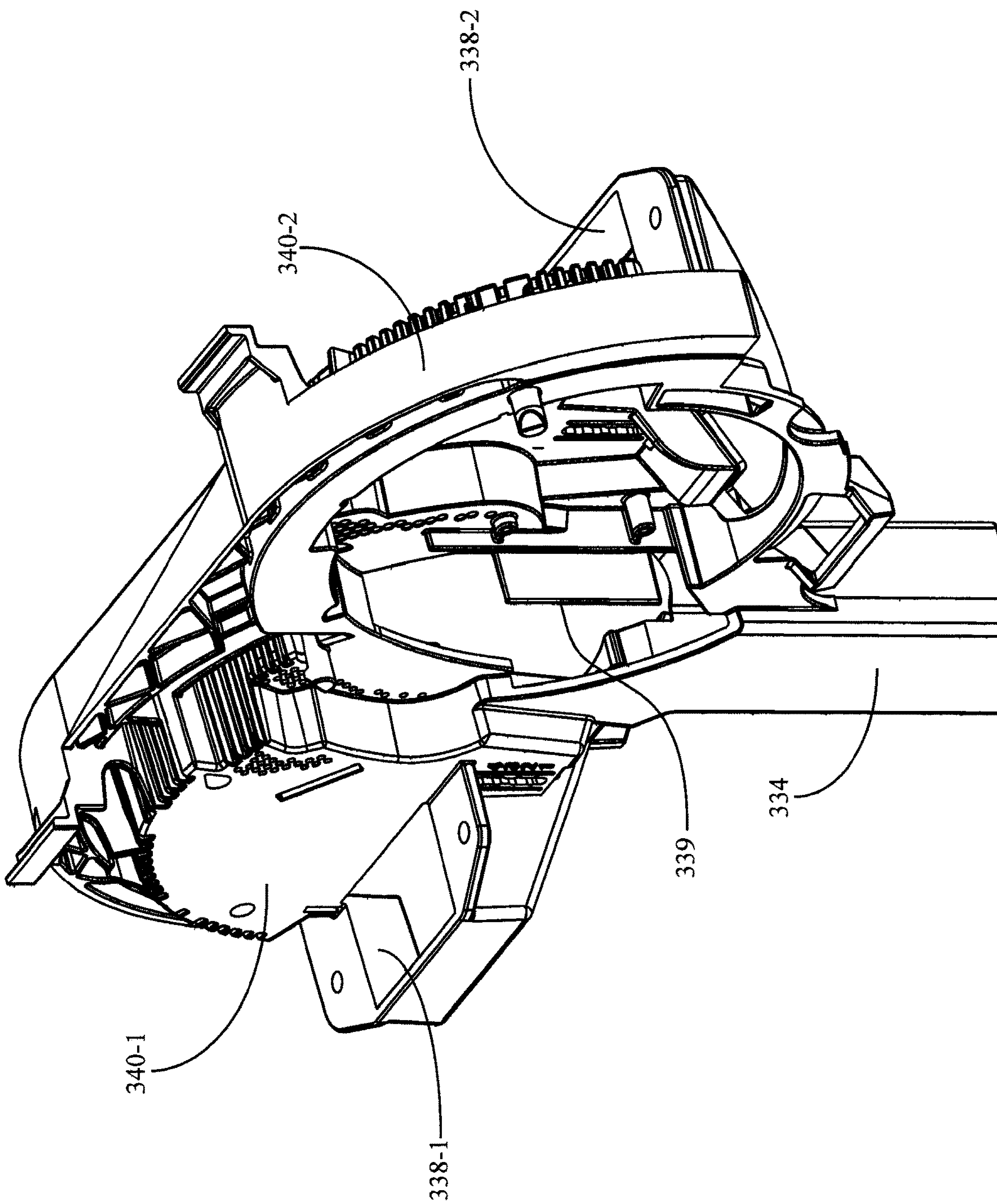


FIG. 29

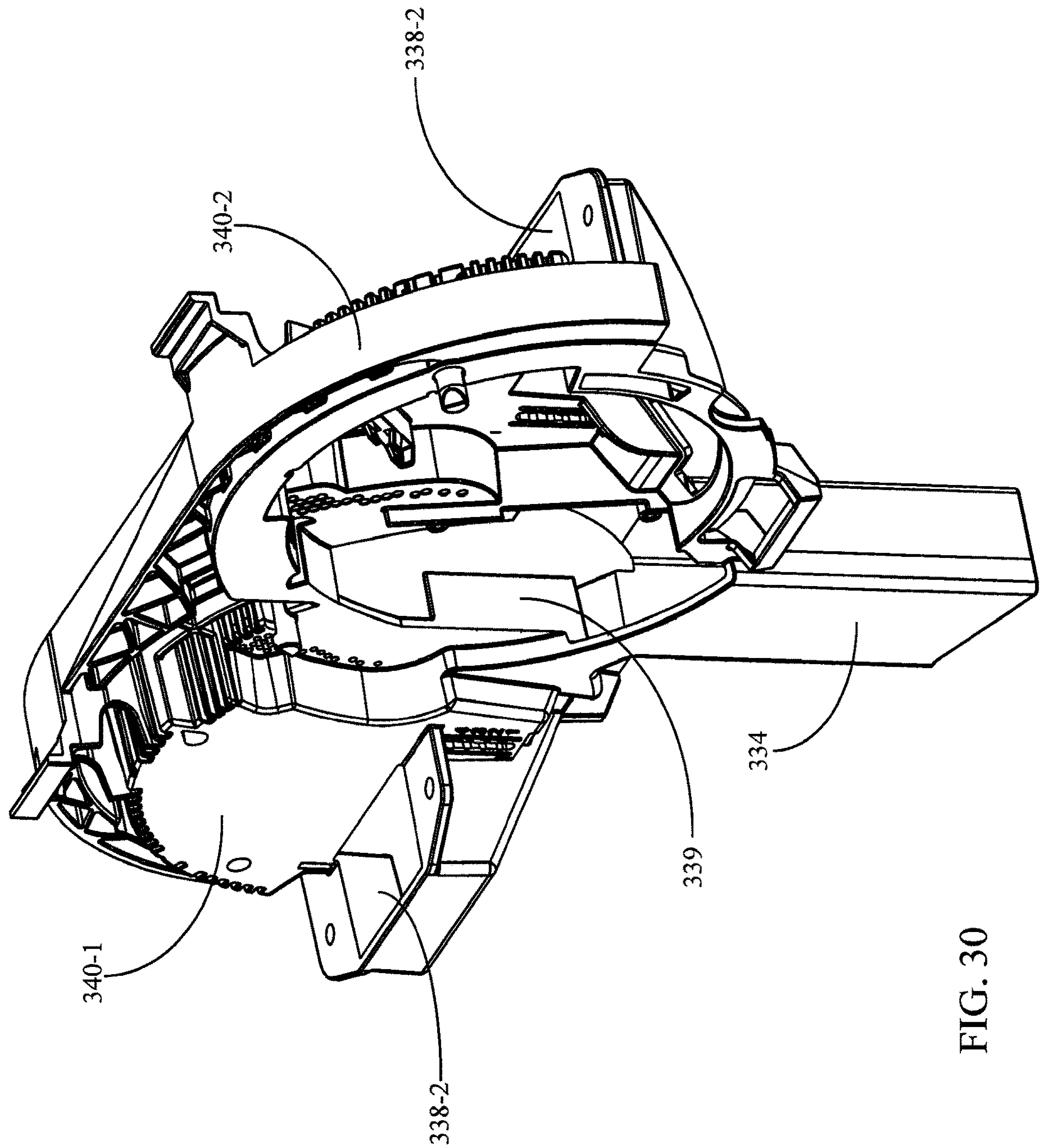


FIG. 30

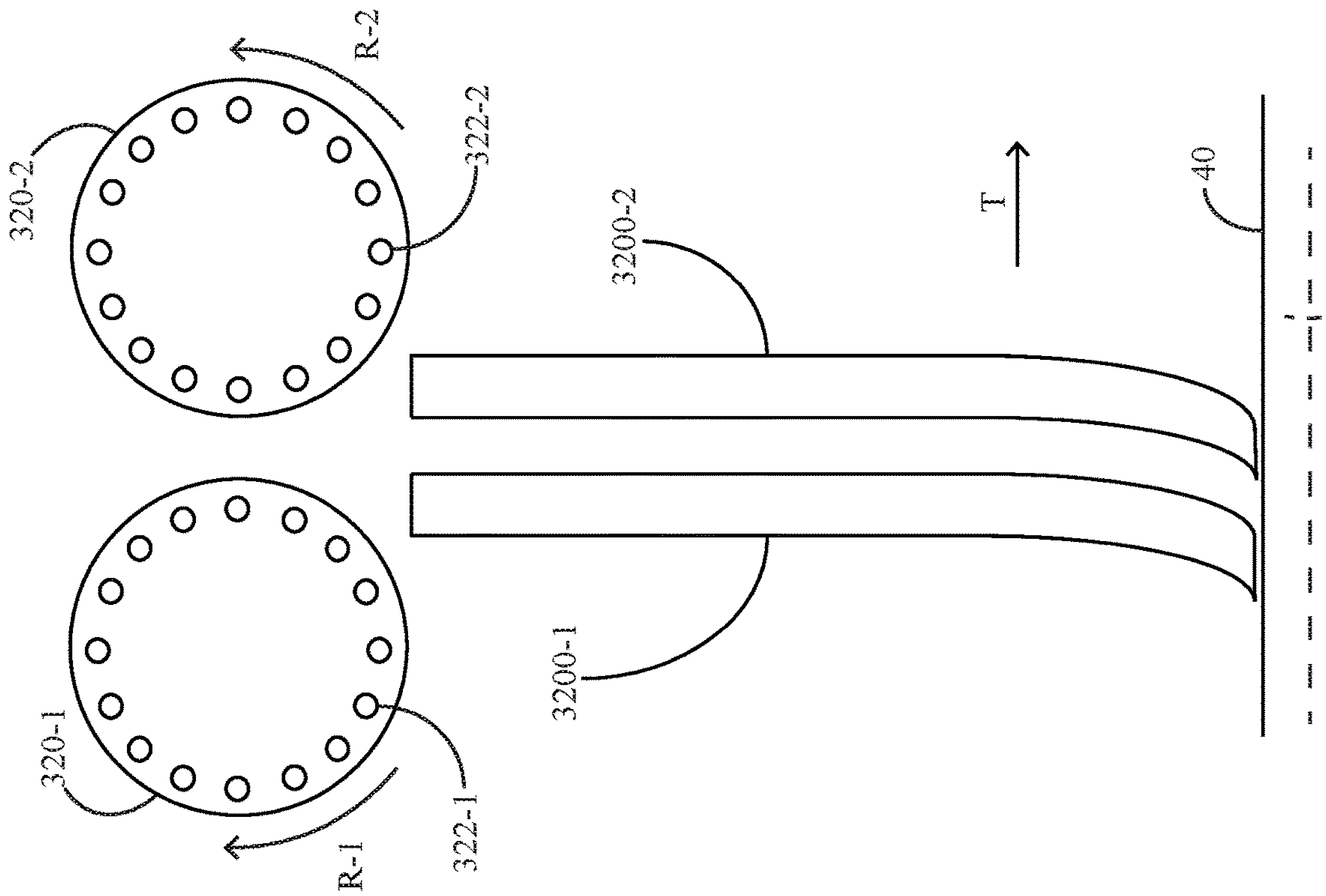

R-2
320-2
322-2
3200-2
T
40
38
3200-1
320-1
322-1
R-1

FIG. 32

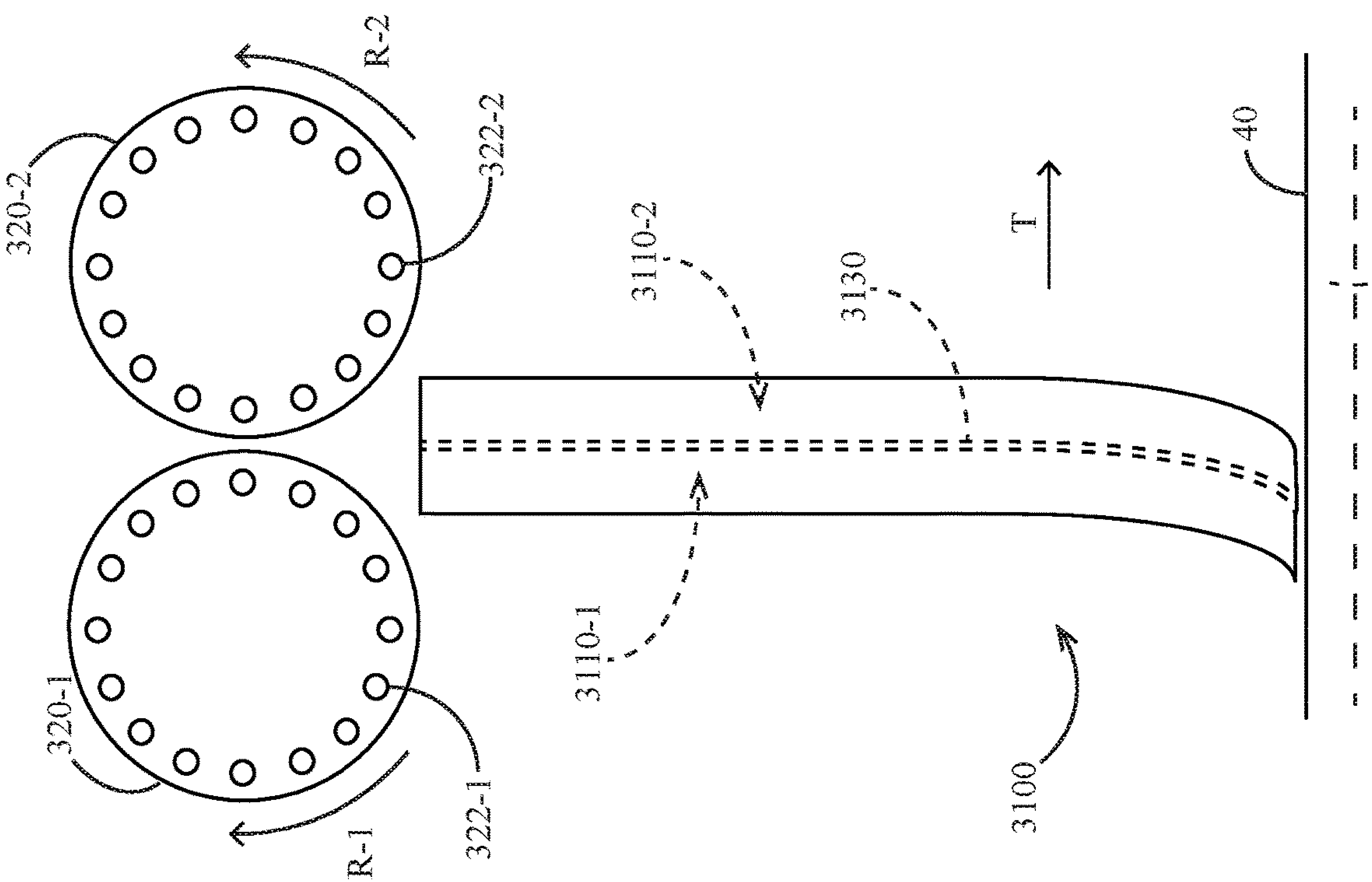

R-2
320-2
322-2
3110-2
3130
T
40
38
3110-1
320-1
322-1
R-1
3100

FIG. 31

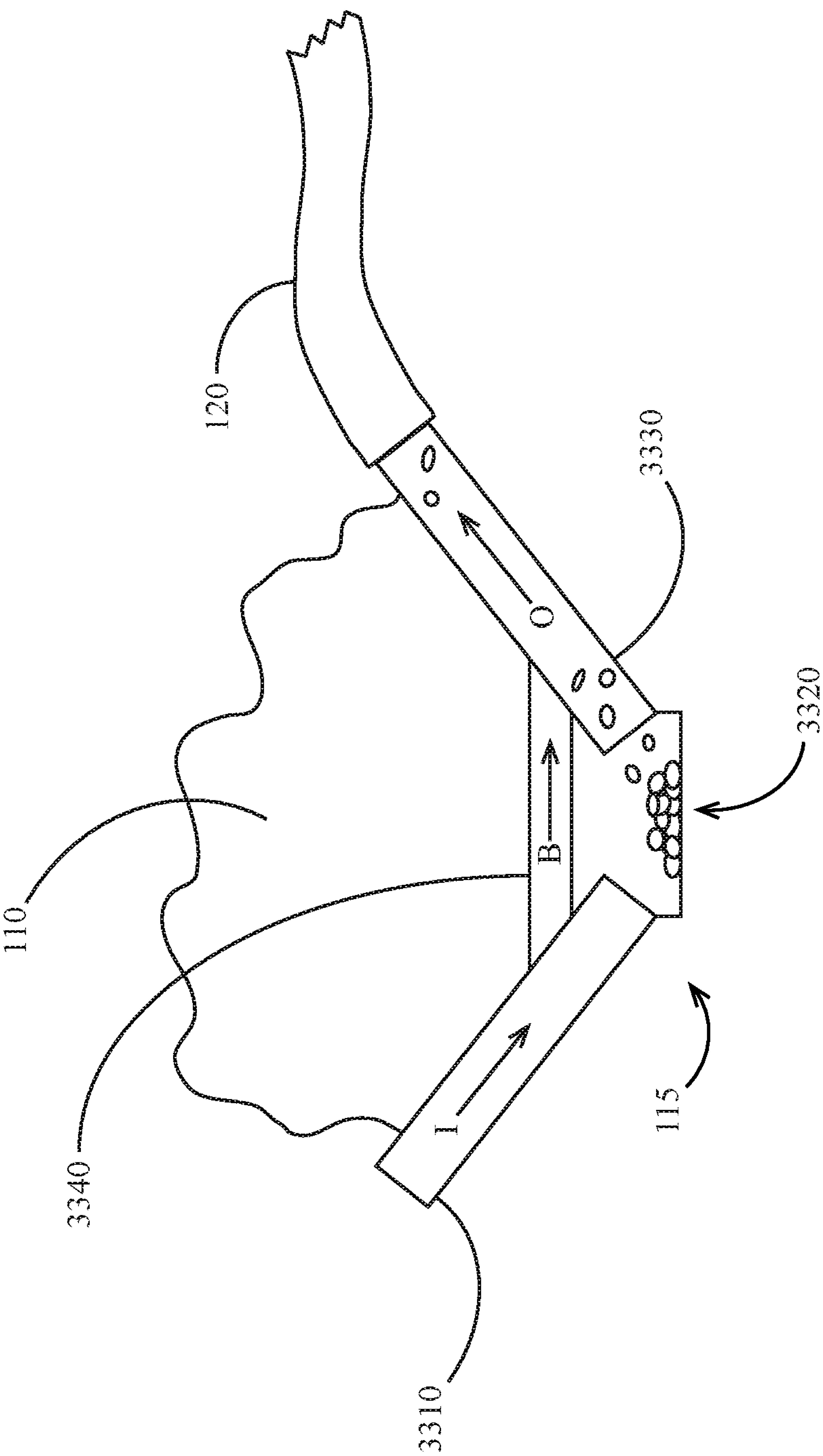


FIG. 33

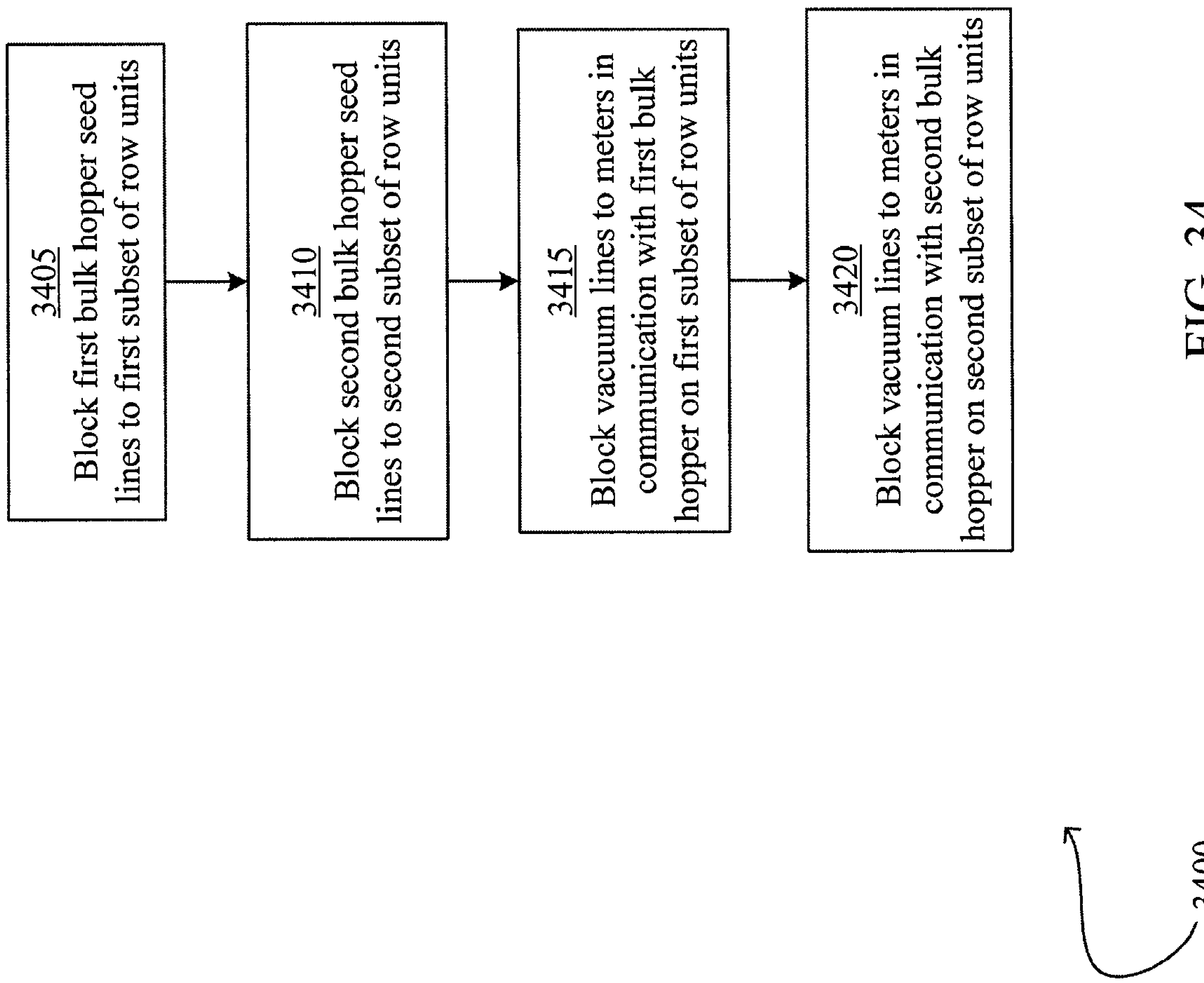

3405
Block first bulk hopper seed lines to first subset of row units
3410
Block second bulk hopper seed lines to second subset of row units
3415
Block vacuum lines to meters in communication with first bulk hopper on first subset of row units
3420
Block vacuum lines to meters in communication with second bulk hopper on second subset of row units
3400

FIG. 34

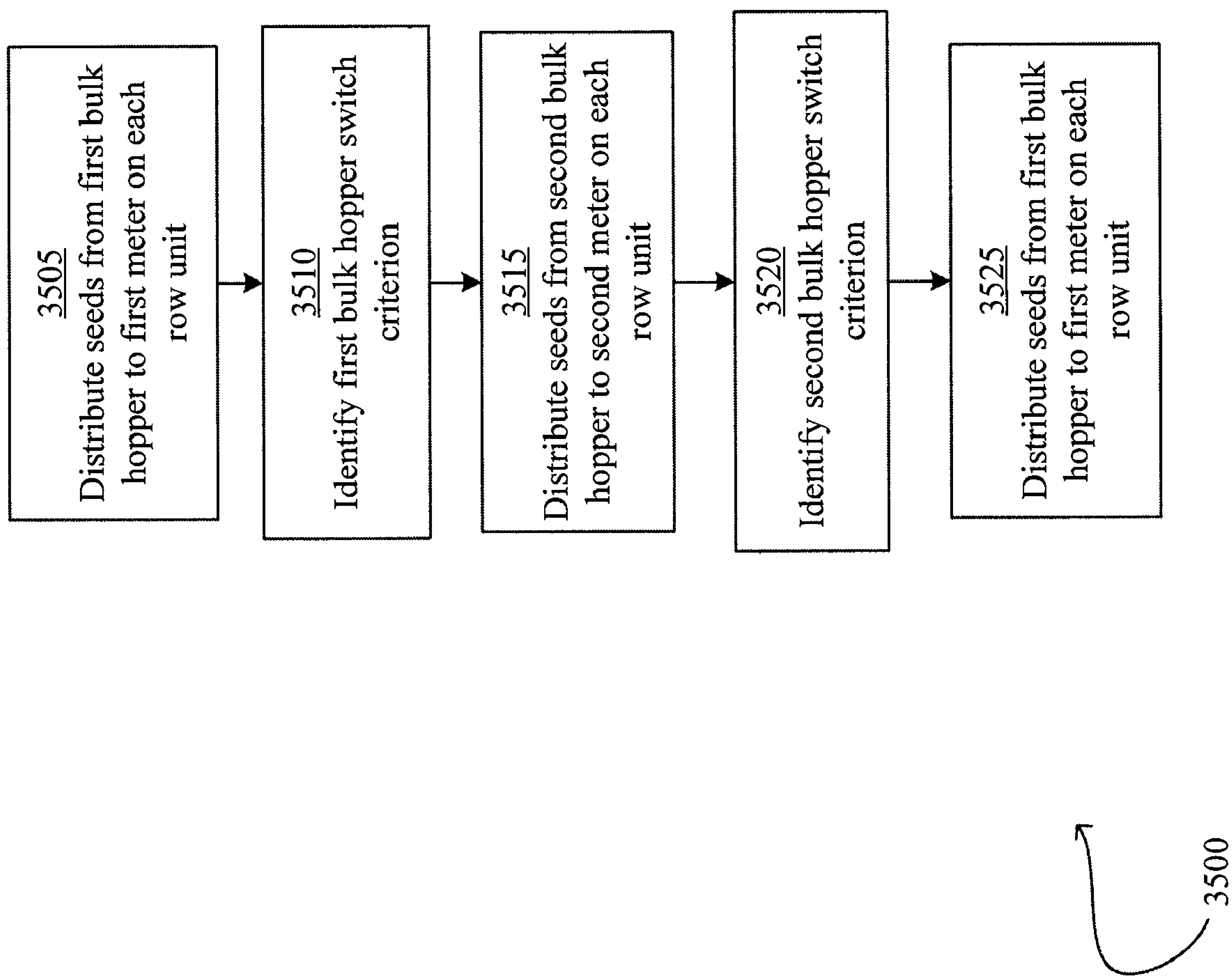

3505
Distribute seeds from first bulk hopper to first meter on each row unit
3510
Identify first bulk hopper switch criterion
3515
Distribute seeds from second bulk hopper to second meter on each row unit
3520
Identify second bulk hopper switch criterion
3525
Distribute seeds from first bulk hopper to first meter on each row unit
3500

FIG. 35

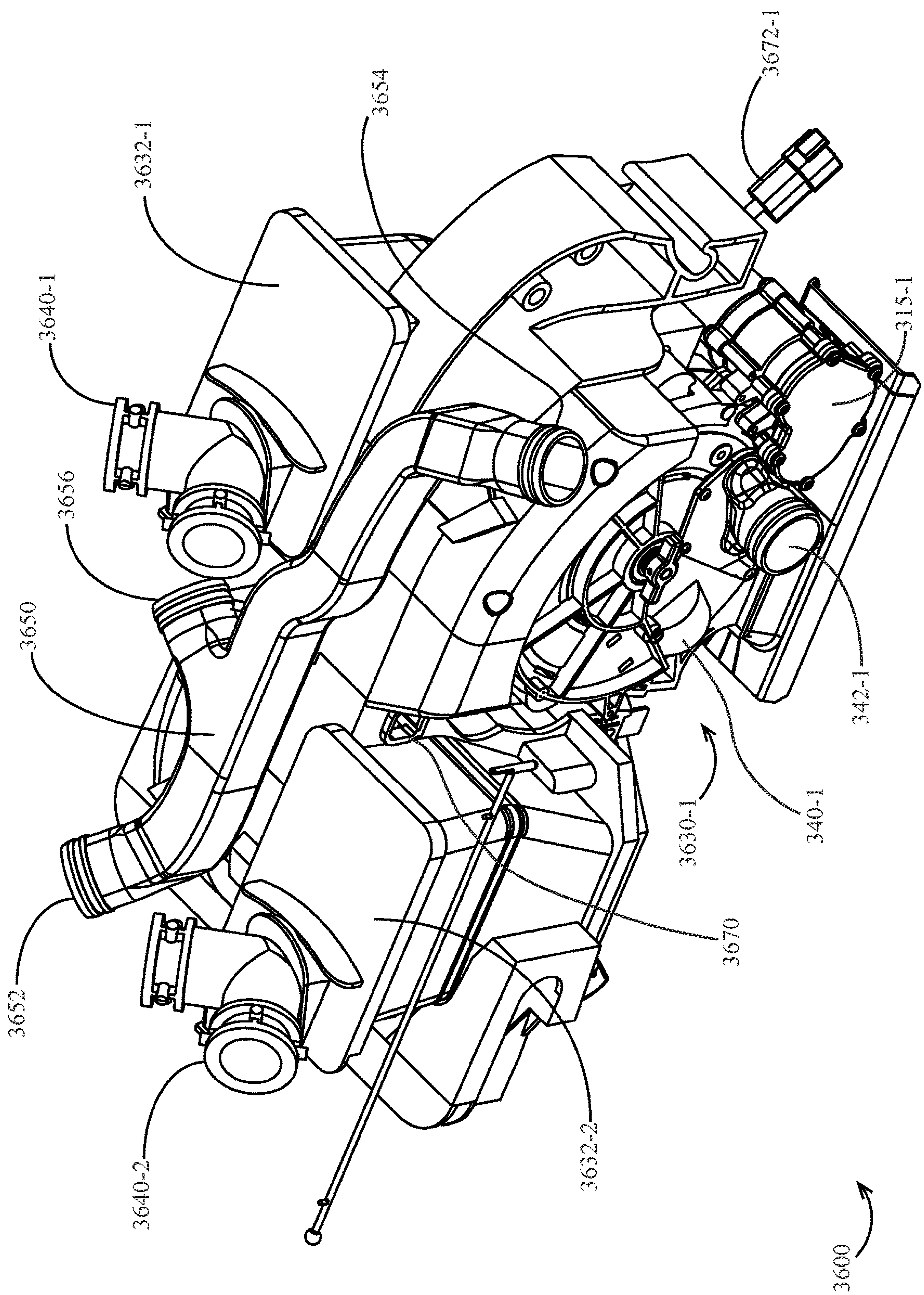

3672-1
3654
3632-1
3640-1
3656
3650
3652
3640-2
3632-2
3670
3630-1
340-1
342-1
315-1
3600

FIG. 36

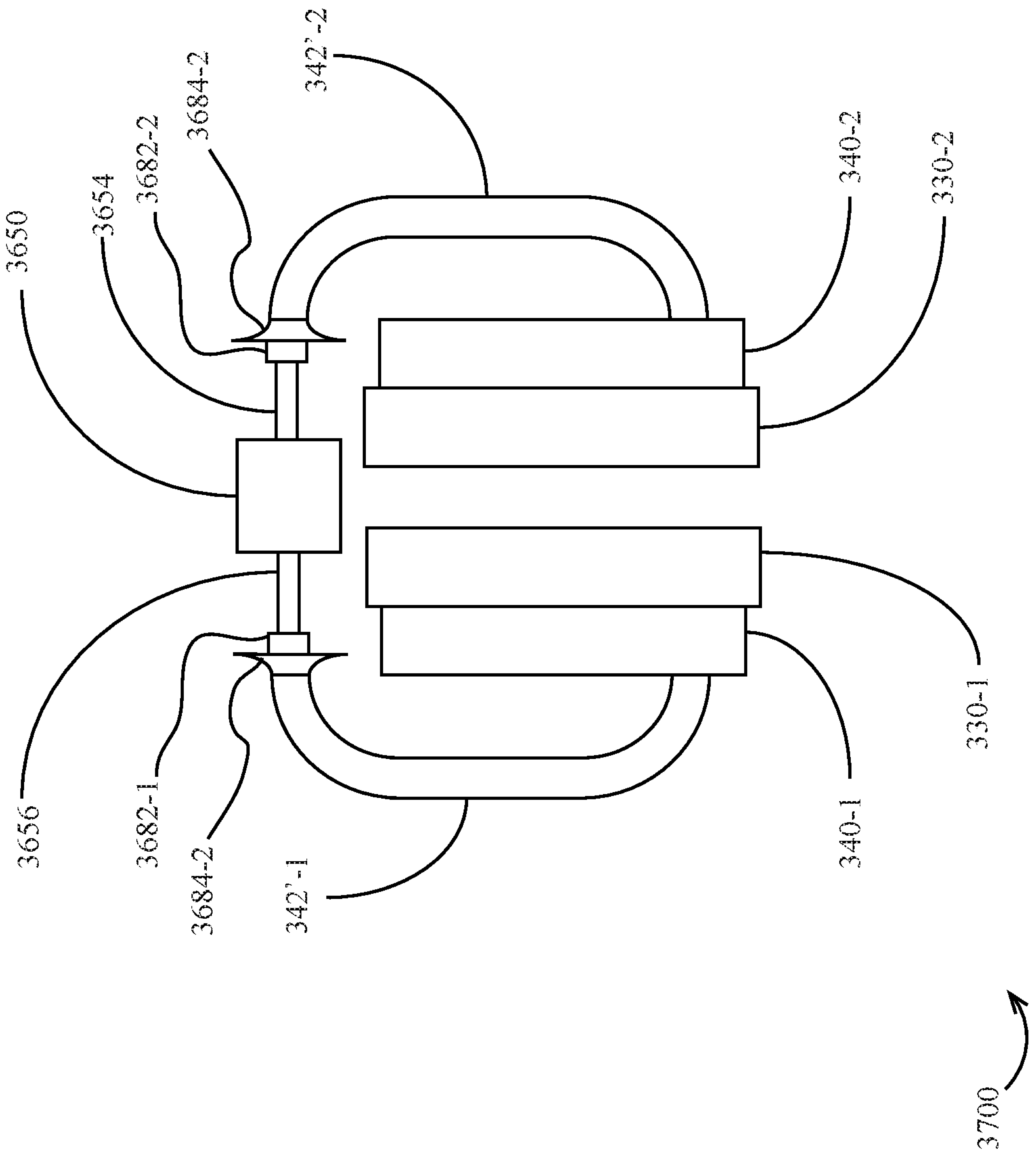

3650
3654
3682-2
3684-2
342'-2
340-2
330-2
3656
3682-1
3684-2
342'-1
340-1
330-1
3700

FIG. 37

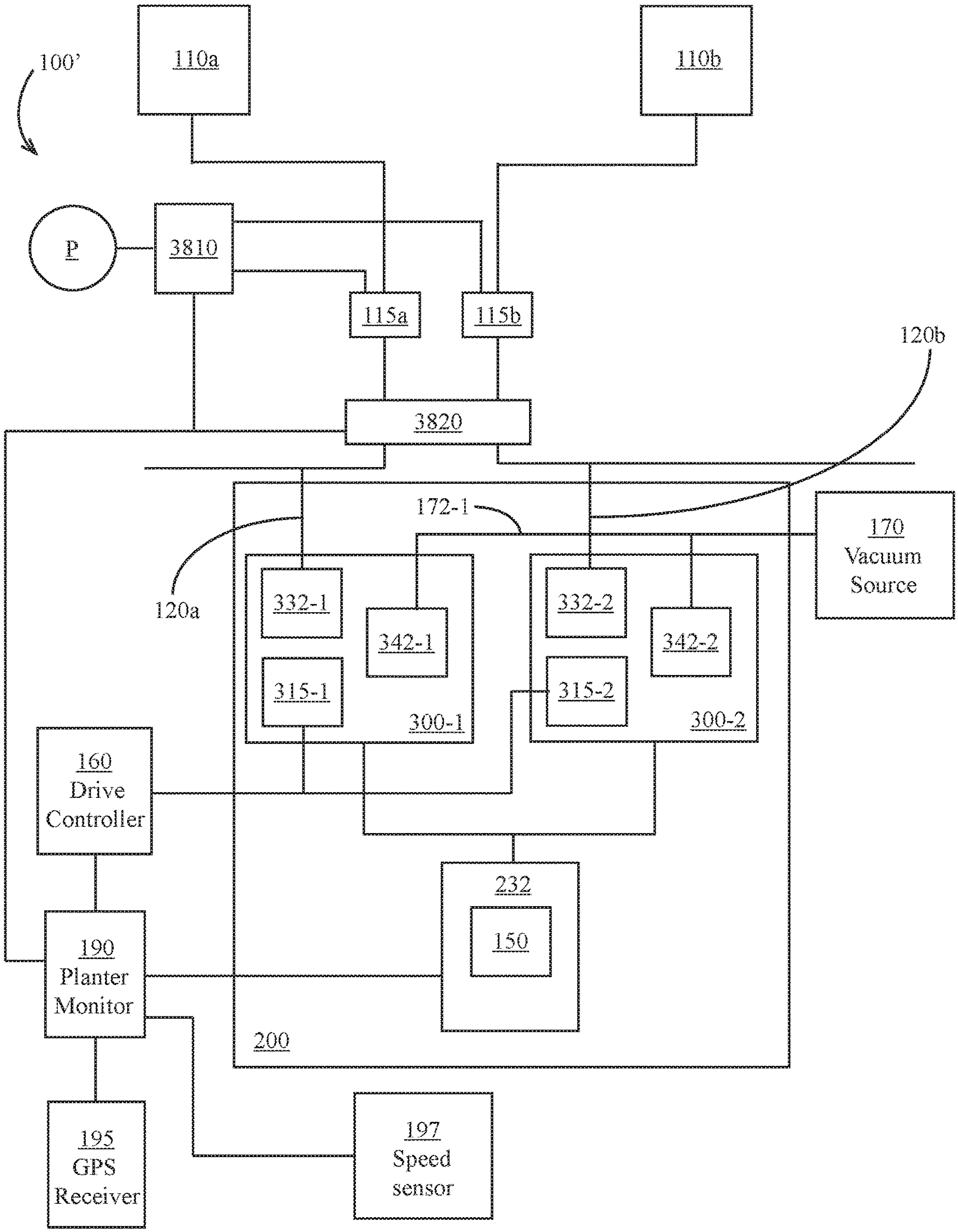

100'
110a
110b
P
3810
115a
115b
120b
3820
172-1
170
Vacuum
Source
120a
332-1
342-1
315-1
300-1
332-2
342-2
315-2
300-2
160
Drive
Controller
232
150
190
Planter
Monitor
200
195
GPS
Receiver
197
Speed
sensor

FIG. 38

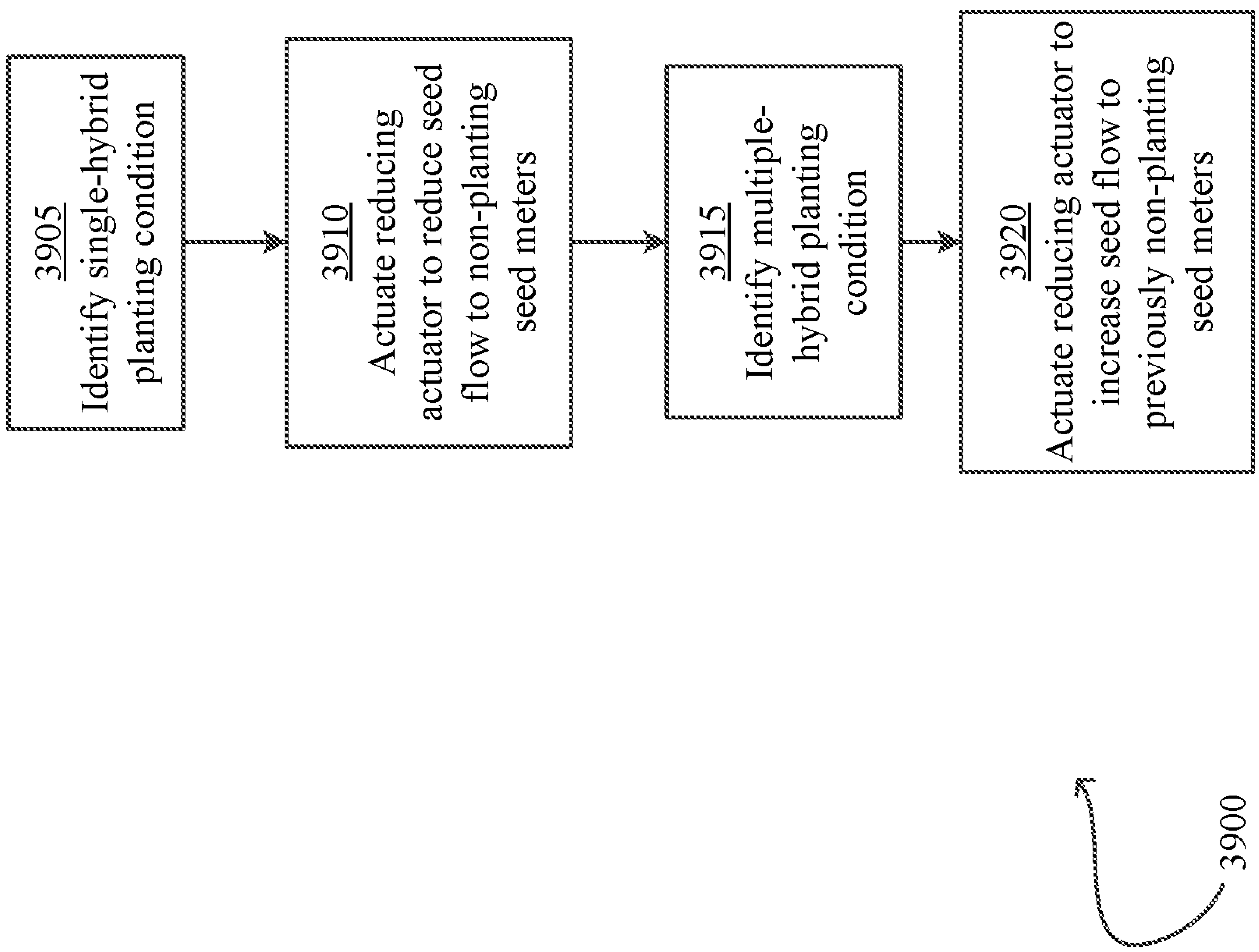

3905
Identify single-hybrid planting condition
3910
Actuate reducing actuator to reduce seed flow to non-planting seed meters
3915
Identify multiple-hybrid planting condition
3920
Actuate reducing actuator to increase seed flow to previously non-planting seed meters
3900

FIG. 39

CROP INPUT VARIETY SELECTION SYSTEMS, METHODS, AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/889,180, "Crop Input Variety Selection Systems, Methods, and Apparatus," filed Feb. 5, 2018, which is a continuation of U.S. patent application Ser. No. 14/832,804, filed Aug. 21, 2015, now U.S. Pat. No. 9,883, 625, which claimed the benefit of the filing date of U.S. Provisional Patent Application 62/088,411, filed Dec. 5, 2014; and U.S. Provisional Patent Application 62/040,205, filed Aug. 21, 2014. The entire disclosures of each of the above applications are incorporated herein by reference.

FIELD

Embodiments of the present disclosure relate generally to systems, methods, and apparatus for planting seeds using row units having seed meters.

BACKGROUND

Information about the technology generally. In recent years, the ability to control crop input applications on a site-specific basis (known as "precision farming") has increased interest in varying input types throughout a field. In particular, advances in seed genetics and agronomic research have increased the need for solutions enabling the variation of seed types in the field during a planting operation. Some proposed solutions involve shifting between input types fed to the metering units, which may result in blending of input types at the metering units and thus blended input regions in the field. Preferred solutions would quickly transition between input types with limited blending between seed types.

Thus there is a need in the art for systems, methods and apparatus for effectively selecting and varying agricultural input types during an in-field operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view of an embodiment of a row crop planter.

FIG. **2** is a side elevation view of an embodiment of a planter row unit.

FIG. **3** schematically illustrates an embodiment of a seed variety selection system.

FIG. **4** is a rear elevation view of certain components of the row unit of FIG. **2**.

FIG. **5** is a plan view of certain components of the row unit of FIG. **2**.

FIG. **6** is a side elevation view of certain components of the row unit of FIG. **2**.

FIG. **7** is a rear elevation view of certain components of another embodiment of a planter row unit.

FIG. **8** is a plan view of certain components of the row unit of FIG. **7**.

FIG. **9** is a side elevation view of certain components of the row unit of FIG. **7**.

FIG. **10** illustrates an embodiment of a process for controlling a planter.

FIG. **11** is a front elevation view of an embodiment a flow splitter.

FIG. **12** is a perspective view of the flow splitter of FIG. **11**.

FIG. **13** is a side elevation view of a planter incorporating the flow splitter of FIG. **13**, illustrating a first row unit of the planter.

FIG. **14** is another side elevation view of the planter of FIG. **13**, illustrating a second row unit of the planter.

FIG. **15** is a side elevation view of a planter row unit incorporating an embodiment of an on-row seed hopper.

FIG. **16**A is a rear elevation view of an embodiment of a seed hopper including a divider in a first position.

FIG. **16**B is a rear elevation view of the seed hopper of FIG. **16**A including divider in a second position.

FIG. **16**C is a rear elevation view of the seed hopper of FIG. **16**A including a divider in a third position.

FIG. **16**D is a rear elevation view of the seed hopper of FIG. **16**A including a divider in a fourth position.

FIG. **16**E is a rear elevation view of the seed hopper of FIG. **16**A including a divider in a fourth position.

FIG. **17** is a plan view of the seed hopper of FIG. **16**A including a divider in the first position.

FIG. **18** is a plan view of an embodiment of a row unit having two seed meters.

FIG. **19** is a side view of an embodiment of a row unit having two seed meters and including disc position sensors.

FIG. **20** is a side view of an embodiment of a planter having a seed hopper supported by a toolbar.

FIG. **21** schematically illustrates an embodiment of a system for selectively driving one of two seed discs via a clutch.

FIG. **22** is a plan view of an embodiment of a row unit including a plurality of edge-release seed discs disposed to deposit seeds into the same seed tube.

FIG. **23**A is a side elevation view of an embodiment of a row unit incorporating three seed meters disposed to deposit seeds into a common seed tube and including an auxiliary seed tube.

FIG. **23**B is a side elevation view of an embodiment of a row unit incorporating three seed meters disposed to deposit seeds into a common seed tube and including a conveyor.

FIG. **24** schematically illustrates an embodiment of a system for supplying vacuum to two seed meters via a valve.

FIG. **25**A is a sectional view of an embodiment of a solenoid-operated valve having a baffle in a first position.

FIG. **25**B is a sectional view of the valve of FIG. **25**A having a baffle in a second position.

FIG. **25**C is a sectional view of the valve of FIG. **25**A having a baffle in a third position.

FIG. **26** is a side elevation view of an embodiment of a row unit including two seed meters.

FIG. **27** is a left front perspective view of the two seed meters of FIG. **26**.

FIG. **28** is a right front perspective view of the two seed meters of FIG. **26**.

FIG. **29** is a left front perspective view of the seed side housings of the two seed meters of FIG. **26**.

FIG. **30** is a left rear perspective view of the seed side housings of the two seed meters of FIG. **26**.

FIG. **31** is a side elevation view of an embodiment of a row unit having a seed tube with two seed channels.

FIG. **32** is a side elevation view of an embodiment of a row unit having two seed tubes.

FIG. **33** is a side cutaway view of an embodiment of an embodiment of an entrainer having a bypass channel.

FIG. **34** illustrates an embodiment of a process for operating a seed variety selection system in a single-hybrid mode.

FIG. **35** illustrates another embodiment of a process for operating a seed variety selection system in a single-hybrid mode.

FIG. **36** illustrates another embodiment of a row unit.

FIG. **37** illustrates still another embodiment of a row unit.

FIG. **38** illustrates another embodiment of a seed variety selection system.

FIG. **39** illustrates an embodiment of a process for actuating a reducing actuator.

DETAILED DESCRIPTION

Variety Selection Systems and Apparatus

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, FIG. **1** illustrates a planter **10** having a frame **12** including a transversely extending toolbar **14**. A plurality of row units **200** are mounted to the toolbar **14** in transversely spaced relation. A plurality of bulk hoppers **110** are preferably supported by the frame **14** and in seed and pneumatic communication with the row units **200**.

Turning to FIG. **2**, an embodiment is illustrated in which the row unit **200** is a planter row unit. The row unit **200** is preferably pivotally connected to the toolbar **14** by a parallel linkage **216**. An actuator **218** is preferably disposed to apply lift and/or downforce on the row unit **200**. A solenoid valve (not shown) is preferably in fluid communication with the actuator **218** for modifying the lift and/or downforce applied by the actuator. An opening system **234** preferably includes two opening discs **244** rollingly mounted to a downwardly-extending shank **254** and disposed to open a v-shaped trench **38** in the soil **40**. A pair of gauge wheels **248** is pivotally supported by a pair of corresponding gauge wheel arms **260**; the height of the gauge wheels **248** relative to the opener discs **244** sets the depth of the trench **38**. A depth adjustment rocker **268** limits the upward travel of the gauge wheel arms **260** and thus the upward travel of the gauge wheels **248**. A downforce sensor (not shown) is preferably configured to generate a signal related to the amount of force imposed by the gauge wheels **248** on the soil **40**; in some embodiments, the downforce sensor comprises an instrumented pin about which the rocker **268** is pivotally coupled to the row unit **200**, such as those instrumented pins disclosed in U.S. patent application Ser. No. 12/522,253 (Pub. No. US 2010/0180695), the disclosure of which is hereby incorporated herein by reference.

Continuing to refer to FIG. **2**, a first seed meter **300-1** such as that disclosed in International Patent Application No. PCT/US2012/030192 ("the '192 application") (Pub. No. WO 2012/129442 A2), the disclosure of which is hereby incorporated herein by reference, is preferably mounted to the row unit **200** and disposed to deposit seeds **42** into the trench **38**, e.g., through a seed tube **232** disposed to guide the seeds toward the trench. In other embodiments, the seed tube **232** is replaced with a seed conveyor such as that disclosed in International Patent Application No. PCT/US2012/057327 ("the '327 application") (Pub. No. WO 2013/049198 A1), incorporated herein by reference. A second seed meter **300-2** such as that disclosed in the '192 application is preferably mounted to the row unit **200** and disposed to deposit seeds **42** into the same trench **38**, e.g., through the same seed tube **232**. In embodiments in which the seed tube is replaced with a seed conveyor, the seed meters **300-1**, **300-2** supply seed into the same seed conveyor; in embodiments in which the seed conveyor includes a loading wheel for urging seed into the seed conveyor, the seed conveyor is preferably configured to alternately urge seeds from the seed meter **300-1** and the seed meter **300-2** into the seed conveyor.

Continuing to refer to FIG. **2**, each of the seed meters **300-1**, **300-2** preferably includes a seed side housing **330** having an auxiliary hopper **332** for storing seeds **42** to be deposited by the meter. Each of the seed meters **300-1**, **300-2** preferably includes a vacuum side housing **340** including a vacuum port **342** for pulling a vacuum within the vacuum side housing. Each of the seed meters **300-1**, **300-2** preferably includes a seed disc **320** including a plurality of seed apertures **322** (see FIG. **6**); the seed disc **320** preferably separates interior volumes of the vacuum side housing **340** and the seed side housing **330**. In operation, seeds **42** communicated from the auxiliary hopper **332** into the seed side housing **330** are captured on the seed apertures **322** due to the vacuum in the vacuum side housing and then released into the seed tube **232**. Each of the meters is preferably powered by individual electric drives **315-1**, **315-2** respectively. Each drive **315** is preferably configured to drive a seed disc **320** within the associated seed meter **300**. Each electric drive **315** preferably comprises an electric drive such as one of the embodiments disclosed in International Patent Application No. PCT/US2013/051971 and/or U.S. Pat. No. 7,617,785, the disclosures of both of which are hereby incorporated herein in their entirety by reference. In other embodiments, the drive **315** may be replaced with a hydraulic drive or other motor configured to drive the seed disc.

An embodiment of the seed meters **300-1**, **300-2** is illustrated in detail in FIGS. **26-30**. Referring to FIGS. **29-30**, the seed meters **300-1**, **300-2** are preferably joined together. The seed side housings **330-1**, **330-2** preferably comprises a unitary part including an exit chute **334** disposed to receive seeds released by both seed meters **300**. The seed sides housings are preferably disposed such that seeds released from the seed discs in both meters **300** (e.g., at the 3 o'clock position) fall into the exit chute **334**. Although in normal operation, seeds should simply free-fall from the 3 o'clock position of the seed disc into the exit chute **224**, a guide surface **339** is preferably disposed to constrain seeds deposited by the seed meter **300-2** to fall down the exit chute if the seed meter **300-2** releases seeds before or after the 3 o'clock position. The exit chute **334** is preferably mounted to an upper end of the seed tube **232** such that the exit chute **334** communicates seeds from both seed meters **300** to the seed tube **232**.

Each of the seed side housings **330** preferably includes an opening **338** in communication with an auxiliary hopper **332**. Referring to FIGS. **27-28**, a shield **380** is preferably mounted to each seed meter **300**. Each shield **380** preferably includes a vent **336** in fluid communication with an interior volume of the seed side housing **330**. A screen (not shown) is preferably mounted to the vent **336** to prevent small particles or debris from entering the vent **336**. The shield **380** is preferably disposed to shield the vent **336** from rain. The shield **380-2** preferably includes a mounting receptacle **382**. The shield **380-1** preferably includes a mounting hook **384**. Referring to FIG. **26**, the row unit **200** preferably includes a mounting bar **282** configured to rotatably engage the mounting receptacle **382**. The row unit **294** preferably includes a latch configured to selectively engage the mounting hook **384**. In an installation phase, the operator preferably engages the mounting receptacle **382** to the mounting bar **282** and rotates the meters **300** downward (clockwise on the view of FIG. **26**) until the exit chute **334** engages the seed tube **232**. The operator then secures the mounting hook **384** to the row unit **200** using the latch **294**. Thus mounting bar **282** and the latch **292** cooperate to selectively retain the seed meters **300** in engagement with the row unit **200** and in communication with the seed tube **232**.

A seed sensor **150** (e.g., an optical or electromagnetic seed sensor configured to generate a signal indicating passage of a seed) is preferably mounted to the seed tube **232** and disposed to send light or electromagnetic waves across the path of seeds **42**. A closing system **236** including one or more closing wheels is pivotally coupled to the row unit **200** and configured to close the trench **38**.

Turning to FIG. **3**, a seed variety selection system **100** is illustrated. The system **100** preferably includes a plurality of bulk hoppers **110** (e.g., two bulk hoppers **110***a* and **110***b* as illustrated). The first bulk hopper **110***a* preferably contains a first seed variety (e.g., a first corn seed variety or a first soybean variety); the second bulk hopper **110***b* preferably contains a second seed variety (e.g., a second corn seed variety or a second soybean variety). Each bulk hopper is preferably in fluid communication with an individual seed entrainer **115**. Each seed entrainer **115** is preferably mounted to a lower outlet of the associated bulk hopper **110**. Each seed entrainer **115** is preferably in fluid communication with a pneumatic pressure source P and configured to convey air-entrained seeds through a plurality of seed lines **120** to the row units **200**. Via a plurality of seed lines **120***a*, the bulk hopper **110***a* and the entrainer **115***a* are preferably in seed communication with a first seed meter **300-1** (e.g., with the auxiliary hopper **332-1**) of each row unit **200** along the toolbar **14**. In operation, the bulk hopper **110***a* supplies the first seed variety to the first meter **300-1** of each row unit **200**. Via a plurality of seed lines **120***b*, the bulk hopper **110***b* and the entrainer **115***b* are preferably in seed communication with a second seed meter **300-2** (e.g., with the auxiliary hopper **332-2**) of each row unit **200** along the toolbar **14**. In operation, the bulk hopper **110***b* supplies the second seed variety to the second meter **300-2** of each row unit **200**.

Continuing to refer to FIG. **3**, each drive **315-1**, **315-2** is preferably in data communication with a drive controller **160**. The drive controller is preferably configured to generate a drive command signal corresponding to a desired rate of seed disc rotation. The drive controller **160** is preferably in data communication with a planter monitor **190**. The planter monitor **190** preferably includes a memory, a processor, and a user interface. The planter monitor is preferably configured to send drive command signals and/or desired rates of seed disc rotation to the drive controller **160**. The planter monitor **190** is preferably in data communication with a GPS receiver **195** mounted to either the planter **10** or the tractor used to draw the planter. The planter monitor **190** is preferably in data communication with a speed sensor **197** (e.g., a radar speed sensor) mounted to either the planter **10** or the tractor. As used herein, "data communication" may refer to any of electrical communication, electronic communication, wireless (e.g., radio) communication, or communication by any other medium configured to transmit analog signals or digital data.

Turning to FIG. **33**, an embodiment of the entrainer **115** is illustrated in detail. Air from the pressure source P enters an inlet **3310**; air in the inlet **3310** generally has a velocity vector I. Air from the inlet **3310** preferably enters a lower portion of the bulk hopper **110** adjacent to a location where a quantity **3320** of seed accumulates by gravity. The air entrains seeds into an outlet **3330**; air in the outlet **3330** generally has a velocity vector O. Seed preferably passes from the outlet **3330** to one of the row units **200** via one of the seed lines **120**. The entrainer **115** preferably includes a bypass channel **3340** extending between the inlet **3310** and the outlet **3330**. The bypass channel **3340** is preferably disposed inside the bulk hopper **110**. The bypass channel **3340** is preferably enclosed from the interior volume of the bulk hopper **110** such that air flows through the bypass channel without obstruction by seeds. Bypass air moving from the inlet **3310** to the outlet **3330** via the bypass channel **3340** generally has a velocity vector B. In some embodiments, a valve (e.g., a ball valve) is disposed in the bypass channel **3340** such that the operator may vary an opening through which air is required to flow in order to pass through the bypass channel. In some embodiments, a plurality of bypass channels in the entrainer each includes a valve; the plurality of valves is preferably controlled by a single manual actuator (e.g., a lever) or in some embodiments, by one or more electrically operated actuators.

In some embodiments, a drive controller **160** associated with each row unit **200** is configured to receive signals from the planter monitor **190** via a bus (e.g., a CAN bus) and to receive motor encoder signals from and send drive command signals to each of the drives **315-1**, **315-2** (e.g., via point-to-point electrical connections). In other embodiments, a separate drive controller **160** is associated with each drive **315**.

In still other embodiments, as illustrated in FIG. **21**, a single drive **315** is configured to alternately drive either of the seed discs **320-1**, **320-2** via a clutch **317** configured to place an output shaft of the motor in operative connection with one or the other of the seed discs **320-1**, **320-2**. The clutch is preferably configured to alternate the operative connection of the drive **315** from one seed disc in response to a clutch command signal. As an illustrative example, the clutch **317** may shift an idler gear between a first and a second position; in the first position the idler gear operably connects the drive **315** to the first seed disc **320-1** for driving the seed disc **320-1**, and in the second position the idler gear operably connects the drive **315** to the second seed disc **320-2** for driving the seed disc **320-2**. The drive controller **160** is preferably in data communication with the clutch **317** for sending clutch command signals to the clutch. The drive controller **160** is preferably configured to receive signals from the planter monitor **190** via a bus (e.g., a CAN bus) and to receive motor encoder signals from and send drive command signals to the single drive **315** (e.g., via point-to-point electrical connections).

Continuing to refer to FIG. **3**, each vacuum port **342** is preferably in fluid communication with a vacuum source **170** via a vacuum line **172**. In some embodiments, the vacuum source **170** comprises a vacuum tube having outlets corresponding to the vacuum ports **342**. In order to reduce loss of vacuum, at least some of the outlets are preferably disposed at an angle less than 90 degrees relative to the vacuum tube; e.g., angled 45 degrees in an outboard direction. The outlets may additionally define a curvilinear flow pattern having an acute outlet angle at the interface between the vacuum tube and each outlet.

Referring to FIGS. **24-25**C, in some embodiments, the vacuum source **170** is in fluid communication with each pair of vacuum ports **342** via a solenoid-operated valve **175**. In the embodiment of the solenoid-operated valve **175** illustrated in FIGS. **25**A-**25**C, the solenoid-operated valve includes an vacuum inlet I in fluid communication with the vacuum source **170**, two vacuum outlets O-**1**, O-**2** in fluid communication with the vacuum ports **342-1**, **342-2**, respectively, and a baffle **177** selectively moveable between three positions in response to a control signal received from the planter monitor **190**, which is preferably in data communication with the solenoid-operated valve. In the first position illustrated in FIG. 25A, the baffle 177 partially blocks flow to the second vacuum port 342-2, establishing only the vacuum level in meter 300-2 necessary to retain seeds on the seed disc 320-2 (e.g., 10 inches of water), and leaving the first outlet O-1 substantially open. In the second position illustrated in FIG. 25B, the baffle 177 partially blocks flow to the first vacuum port 342-1, establishing only the vacuum level in meter 300-1 necessary to retain seeds on the seed disc 320-1 (e.g., 10 inches of water), and leaving the second outlet O-2 substantially open. In the third position illustrated in FIG. 25C, the baffle 177 preferably leaves both outlets O-1, O-2 substantially open. In operation, the planter monitor 190 preferably commands the valve 175 to shift to the first position when only the first meter 300-1 is planting (e.g., when only the drive 315-1 is commanded to drive), commands the valve 175 to shift to the second position when only the first meter 300-2 is planting (e.g., when only the drive 315-2 is commanded to drive), and commands the valve 175 to shift to the third position when both meters 300 are planting (e.g., when both drives 315 are commanded to drive).

Continuing to refer to FIG. 3, both the first seed meter 300-1 and the second seed meter 300-2 of each row unit 200 are preferably in seed communication with (e.g., disposed to deposit seed into) a seed tube 232 associated with the row unit 200. The seed sensor 150 associated with the seed tube 232 of each row unit 200 is preferably in data communication with the planter monitor 190.

In other embodiments of the variety selection system 100, a third bulk hopper is in fluid and seed communication with the second seed meter 300-2 on all or a subset of the row units 200. In such embodiments, the third bulk hopper may be filled with refuge seed. In still other embodiments, the third bulk hopper may be filled with another granular input such as granular fertilizer. In some embodiments, the third bulk hopper is in fluid and seed communication with a third seed meter on all or a subset of the row units 200, the third seed meter preferably disposed to deposit seed into the same seed tube 232 as the first and second meters 320-1, 320-2.

In some embodiments, a third seed meter 320-3 is disposed above the second meter 320-2 as illustrated in FIGS. 23A and 23B and preferably disposed to release seeds into the same seed tube 232, preferably along the same transverse plane Pt, and preferably along the same longitudinal plane P1. The third seed meter 320-3 preferably rotates in a direction R-3 equivalent to the direction R-1. In the embodiment of FIG. 23A, an auxiliary seed tube 392 is disposed to guide seeds from the third meter 320-3 toward the seed tube 232; as illustrated, the auxiliary seed tube is disposed below the seed release point of the third meter 320-3 and above the seed tube 232 and arranged vertically between the seed release point of the third seed meter 320-3 and the seed release point of the seed meters 320-1, 320-2. In the embodiment of FIG. 23B, a flighted belt 394 is disposed to guide seeds from the third meter 320-3 toward the seed tube 232; as illustrated, the flighted belt is disposed to receive seeds released from the third meter 320-2 the release seeds at a point vertically above the seed tube 232. A backing wall 396 is preferably disposed to retain seeds on the flighted belt 395 during vertical travel prior to release.

An embodiment of the row unit 200 is illustrated in FIGS. 4-6. The seed discs 320-1, 320-2 (of the seed meters 300-1, 300-2, respectively) are disposed at a lateral offset Dh from a central vertical plane P1 of the seed tube 232. The meters 300 preferably release seeds 42 at approximately the 3 o'clock position (along the view of seed disc 320-1 in FIG. 6) of the seed disc, e.g., by vacuum cutoff as is known in the art. The central rotational axes of the seed meters 320-1, 320-2 are preferably offset longitudinally rearward and forward, respectively, of a transverse plane Pt intersecting an inlet of the seed tube 232 such that seeds are released into the seed tube. As illustrated in FIG. 6, the seed discs 320-1, 320-2 preferably rotate in opposite directions R-1, R-2, respectively, in operation of the seed meters 300. The seed discs 320-1, 320-2 preferably release seeds 42 along arcuate paths A-1, A-2 respectively such that each seed travels laterally inboard of the associated seed disc as the seed falls from the disc. It should be appreciated that such arcuate release of seeds may be effected by one or more features of the seed disc; for example, the seed apertures 322 are preferably chamfered such that the seeds are released along an angled surface. The offset Dh is preferably selected such that the seeds 42 released from both seed discs 320 fall into the seed tube 232, preferably adjacent to the plane P1. The offset Dh is preferably between 0.1 and 0.75 inches and is preferably about 0.5 inches. Because the seed tube 232 is preferably in substantial alignment with the trench 38, such release of seeds into the transverse center of the seed tube 232 ensures that the seed tube 232 deposits seeds into the transverse center of the trench 38 formed by the row unit 200. Thus the seed meters 300 mounted to the row unit 200 are configured and disposed to release seeds into the transverse center of the trench 38 opened by the row unit 200.

A second embodiment of the row unit 200' is illustrated in FIGS. 7-9. In the second embodiment, seeds 42 are released from the seed discs 320-1, 320-2 along substantially vertical paths V-1 and V-2, respectively. Seeds 42 enter the upper inlet of a modified seed tube 232' at positions transversely spaced from the seed tube, e.g., transversely spaced from the plane P1. The modified seed tube 232' preferably includes a guide surface 234 configured to guide the seeds from their transversely spaced entry points at the upper inlet of the seed tube to the plane P1 prior to release from the seed tube. The lateral offset Dh of the seed discs 320 is preferably smaller in the second embodiment, e.g., between 0 and 0.5 inches. In some embodiments, the longitudinal offsets of the central rotational axes of the seed discs 320 from the plane Pt are different such that seeds are released from the discs 320-1, 320-2 rearward and forward, respectively, of the plane Pt. In such embodiments, the variation in longitudinal offset is preferably selected such that the seed discs and seeds do not interfere with one another and such that seeds are released into the upper inlet of the seed tube 232.

A third embodiment of the row unit 200" is illustrated in FIG. 18. In the third embodiment, the seed discs 320-1, 320-2 are substantially longitudinally aligned and rotate in the same direction. As with embodiments described above, seeds 42 are released from the seed discs 320 into a common seed tube.

A fourth embodiment of the row unit 200"' is illustrated in FIG. 22. In the fourth embodiment, a plurality of modified seed discs 320' are configured to capture seeds 42 on and release seeds from a peripheral edge of the seed disc. In such an embodiment, the seed discs preferably comprise one of the seed disc embodiments disclosed in U.S. patent application Ser. No. 12/399,173 (Pub. No. US 2010/0224110 A1) and/or U.S. Pat. No. 7,152,542, both of which are incorporated herein by reference. It should be appreciated that with the use of such seed discs, a plurality of seed discs (in the illustrated embodiment, four seed discs 320-1' through 320-4') may be more easily arranged to release seeds in the same seed tube 232 and preferably to release seeds adjacent to the same vertical line (e.g., the intersection of planes Pt and P1).

Moreover, such discs may be oriented at offset angular positions about a vertical axis (e.g., at about 90 degrees as illustrated) and release seeds adjacent to the same vertical line without contacting one another. In the embodiment of FIG. **22**, each seed disc is preferably in communication with a distinct seed source as described elsewhere herein, e.g., the seeds **42-1** through **42-4** are preferably drawn from four distinct hoppers.

A fifth embodiment of the row unit is illustrated in FIG. **31**. In the fifth embodiment, the row unit includes a seed tube **3100** having two seed channels **3110-1** and **3110-2**. The seed channel **3110-1** is preferably disposed to receive seeds falling by gravity from the first seed disc **320-1** (e.g., having an upper opening vertically below the seed release location of the first seed disc **320-1**) and to deposit seeds into the trench **38**. The seed channel **3110-2** is preferably disposed to receive seeds falling by gravity from the first seed disc **320-2** (e.g., having an upper opening vertically below the seed release location of the first seed disc **320-2**) and to deposit seeds into the trench **38**. The seed channel **3110-2** is preferably disposed longitudinally forward of the seed channel **3110-1** along the direction of travel T of the row unit. The seed channels **3110-1**, **3110-2** are preferably separated by a wall **3130**. The seed channels **3110-2** and the wall **3130** are preferably curved rearwardly at a lower end in order to guide seeds rearwardly before release into the trench **38**.

A sixth embodiment of the row unit is illustrated in FIG. **32**. In the fifth embodiment, the row unit includes two seed tubes **3200-1**, **3200-2**. The seed tube **3200-1** is preferably disposed to receive seeds falling by gravity from the first seed disc **320-1** (e.g., having an upper opening vertically below the seed release location of the first seed disc **320-1**) and to deposit seeds into the trench **38**. The seed tube **3200-2** is preferably disposed to receive seeds falling by gravity from the first seed disc **320-2** (e.g., having an upper opening vertically below the seed release location of the first seed disc **320-2**) and to deposit seeds into the trench **38**. The seed tube **3200-2** is preferably disposed longitudinally forward of the seed channel **3200-1** along the direction of travel T of the row unit. The seed tubes **3200** are preferably curved rearwardly at a lower end in order to guide seeds rearwardly before release into the trench **38**.

In other embodiments of the row unit **200**, the meters **300** mounted to the row unit **200** release seeds into separate seed tubes or seed conveyors disposed to drop seeds into the same trench **38** opened by the row unit.

In other embodiments of the row unit **200**, more than two seed meters **300** (e.g., three or four) are mounted to each row unit **200** and configured and disposed to release seeds into the trench **38** opened by the row unit. In such embodiments, more than two bulk hoppers **110** (e.g., three or four) are supported by the frame **12** and in seed communication with the meters (e.g., the third bulk hopper **110** is in seed communication with the third seed meter on each row unit **200**).

In other embodiments of the row unit **200**, a single drive **315** is coupled to both seed discs **320** and configured to simultaneously drive both seed discs. In such embodiments, each meter **300** preferably includes a clutch device (not shown) configured to prevent the meter from depositing seeds. Such a clutch device may comprise a vacuum cutoff device such as that disclosed in U.S. Pat. No. 8,234,988, incorporated herein by reference.

Seed Flow Splitter Embodiments

Referring to FIGS. **11-14**, in some embodiments, a flow splitter **1100** is used to divide flow of seed from a single bulk hopper **110** to supply two row units **200** with seed.

Turning to FIG. **13**, a first flow splitter **1100*a*** is preferably mounted to the toolbar **14** by a bracket **1190*a*** such that the splitter **1100*a*** is disposed above the toolbar. Mounting hooks **1145** (FIG. **12**) are preferably used to mount the flow splitter **1100*a*** to the bracket **1190*a***. An inlet of the flow splitter **1100*a*** is preferably in fluid and seed communication with the bulk hopper **110*a*** (see FIG. **3**) via the seed line **120*a***. A first outlet of the flow splitter **1100*a*** is preferably in fluid and seed communication with the auxiliary hopper **332-1** of a first row unit **200-1** via a secondary seed line **122*a*-1**. A second outlet of the flow splitter **1100*a*** is preferably in fluid and seed communication with the auxiliary hopper **332-1** of a second row unit **200-2** via a secondary seed line **122*a*-2** (see FIG. **14**).

Turning to FIG. **14**, a second flow splitter **1100*b*** is preferably mounted to the toolbar **14** by a bracket **1190*b*** such that the splitter **1100*b*** is disposed above the toolbar. An inlet of the flow splitter **1100*b*** is preferably in fluid and seed communication with the bulk hopper **110*b*** (see FIG. **3**) via the seed line **120*b***. A first outlet of the flow splitter **1100*b*** is preferably in fluid and seed communication with the auxiliary hopper **332-1** of the second row unit **200-2** via a secondary seed line **122*b*-2**. A second outlet of the flow splitter **1100*b*** is preferably in fluid and seed communication with the auxiliary hopper **332-2** of the first row unit **200-1** via a secondary seed line **122*b*-1** (see FIG. **14**).

Turning to FIGS. **11** and **12**, the flow splitter **1100** is illustrated in more detail. The flow splitter **1100** preferably includes an inlet **1110**, an inlet flow portion **1120**, a first split flow portion **1130-1**, a second split flow portion **1130-2**, a first outlet **1140-1**, and a second outlet **1140-2**. The inlet **1110** preferably includes coupling features **1115** for twist-and-lock coupling with the seed line **120**. The outlets **1140** preferably include hose coupling ribs **1145** for securing the outlets to secondary seed lines **122**.

In operation of the flow splitter **1100**, seed entering the inlet **1110** preferably has a generally approximately horizontal flow path. When the flow splitter **1100** is installed on the planter, the inlet flow portion **1120** preferably defines a flow and seed velocity vector Vi less than 70 degrees from vertical and preferably approximately vertical. When the flow splitter **1100** is installed on the planter, the inlet flow portion **1120** preferably defines an air and seed velocity vector Vi less than 70 degrees from vertical and preferably approximately vertical. After traveling through the inlet flow portion **1120**, seed and air flow divides between the first split flow portion **1130-1** and the second split flow portion **1130-1**. When the flow splitter **1100** is installed on the planter, each split flow portion **1130** preferably defines an air and seed velocity vector Vs less than 70 degrees from vertical and preferably approximately vertical. Each split flow portion **1130** preferably defines the velocity vector Vs over a travel distance Dv sufficient to allow seeds traveling only by momentum (i.e., not under the influence of air flow) to slow from its entry speed to a full stop such that the seed does not travel to the outlet **1140** without being influenced by air flow. In preferred embodiments, the distance Dv is preferably greater than about 1.5 inches. In the illustrated embodiment, when travelling from the split flow portion **1130** to the outlet **1140**, seed and air flow preferably changes direction by an angle greater than 90 degrees. When the flow splitter **1100** is installed on the planter, the outlets **1140** preferably each define an air and seed velocity vector Vo more than 20 degrees below horizontal and preferably approximately 45 degrees below horizontal.

In other embodiments, the splitters **1100** are replaced with flow splitters mounted to the row units **200** as disclosed in

U.S. Pat. No. 7,025,010, the disclosure of which is hereby incorporated by reference herein. In such embodiments, a seed line from a first bulk hopper is in fluid and seed communication with an inlet of a flow splitter on a first row unit, a first outlet of the flow splitter is in fluid and seed communication with a seed meter on the first row unit, and a second outlet is in fluid and seed communication with a seed meter on the second row unit. In such embodiments, the first outlet is preferably connected directly to the seed meter on the first row unit via a quick-connect coupler such as a twist-and-lock coupler. Further, the second outlet is preferably connected to the seed meter on the second row unit via a secondary seed line; the secondary seed line is preferably connected to an inlet of a second flow splitter on the row unit via a quick-connect coupler such as a twist-and-lock coupler.

Row Unit Seed Hopper Embodiments

Referring to FIGS. **15-17**, in alternative embodiments, one or both seed meters **300** on the row unit **200** are in seed communication with a seed hopper **1500** supported by the planter. Each seed meter is preferably in communication with a seed containing volume **1525**; in operation, seed from the hopper **1500** preferably enters the seed side housing of the meter **300** after traveling by gravity down an inclined surface **1510**. Referring to FIG. **17**, an inclined surface **1512** preferably guides seed by gravity toward the inclined surface **1510-1**; for example, on the view of FIG. **17** the rightmost end of the surface **1512-1** is preferably at a higher elevation than the leftmost end of the surface **1512-1**. Each seed containing volume **1525** is preferably approximately 1.6 bushels or greater. In the illustrated embodiment, a single seed hopper **1500** includes a single interior volume **1520** separated into two seed containing volumes **1525-1**, **1525-2** by a divider **1515**; the interior volume **1520** is preferably approximately 3 bushels or greater. Referring to FIG. **16**B, in a preferred embodiment the divider **1515** may be selectively tipped into an orientation in which seed added to the hopper **1500** is only communicated to the seed meter **300-1**; in this orientation, the seed containing volume **1525-1** is preferably larger than in the configuration of FIG. **16**A. Referring to FIGS. **16**C through **16**E, another embodiment of a divider **1515'** may be inserted into one of a plurality of vertical guide slots (not shown) in the hopper **1500** in order to selectively vary the ratio of seed types in the hopper. As illustrated, the divider **1515'** preferably includes a vertical sidewall portion and an angled portion which cooperate to define two unequal volumes in the seed hopper. In FIG. **16**C, the divider **1515'** is in a first position in which the seed containing volume **1525-1** is larger than the seed containing volume **1525-2**. In FIG. **16**D, the divider **1515'** is in a second position in which the seed containing volume **1525-2** is larger than the seed containing volume **1525-1**. In FIG. **16**E, the divider is in a third position in which the vertical sidewall divides the hopper **1500** such that the seed containing volumes **1525-1** and **1525-2** have substantially equal similar volumes.

Toolbar Seed Hopper Embodiments

Referring to FIG. **20**, in some embodiments, a plurality of seed hoppers are mounted to the toolbar **14** for supplying seed to the meters **300** on the row units **200**. In the illustrated embodiment, the seed hoppers comprise seed hoppers **1500** described above, mounted to the toolbar **14** via a bracket **1590**. Each seed hopper is preferably in seed communication with two seed meters **300** via seed lines **122**, preferably in a similar fashion to the lines connecting the splitters **1100** described above with respect to FIGS. **13** and **14**. The seed hopper **1500** is preferably mounted in an elevated position relative to the meters **300** such that seed descends through the tubes by gravity. In the illustrated embodiment, a first seed hopper **1500***a* supplies a first seed type to the seed meter **300-1** on a first row unit **200-1** and supplies the first seed type to a seed meter **300-1** on a second row unit **200-2** (not shown); thus in the illustrated embodiment, no divider **1515** is preferably inserted in the hopper **1500***a* and the hopper is preferably filled only with the first seed type. In the illustrated embodiment, a second seed hopper **1500***b* (not shown) is preferably similarly mounted to the toolbar and in seed communication with seed meters **300-2** on the row unit **200-1** as well as the row unit **200-2** (not shown) for supplying a second seed type to the seed meters **300-2** on the row units **200-1**, **200-2**. In other embodiments, the hopper **1500** is in seed communication with the first seed meter **300-1** on the row unit **200-1** as well as the second seed meter **300-2** on the row unit **200-1**; in such embodiments, a divider **1515** is preferably inserted in the hopper **1500** and the two resulting seed containing volumes are filled with the first seed type and the second seed type, respectively.

Drive Control Methods

Turning to FIG. **10**, a process **1000** is illustrated for selecting a seed variety planted by the one of the embodiments of the row unit **200** of the variety selection system **100**. At step **1005**, the planter monitor **190** preferably accesses a seed variety map, preferably stored in the memory of the planter monitor. The seed variety map preferably comprises a file (e.g., a shape file) associating desired seed types with geo-referenced locations. In other embodiments, two separate shape files may be used to independently control the meters **300**; in such embodiments, the a first map file preferably instructs the first meter not to plant at locations for which the second map file instructs the second meter to plant, and vice versa. At step **1010**, the planter monitor **190** preferably identifies the nearest variety boundary (i.e., boundary at which the currently desired seed variety is no longer desired and a different seed variety is desired) along the current path traveled by the row unit **200**. At step **1015**, the planter monitor **190** preferably obtains the speed of the row unit **200** using one of the methods disclosed in the '327 application. At step **1020**, the planter monitor **190** preferably estimates the time to the nearest variety boundary, e.g., by dividing the distance to the variety boundary by the speed of the row unit. At step **1025**, the planter monitor **190** preferably compares the time estimated at step **1020** to a first predetermined delay and commands the first drive **315-1** to stop when the time estimated at step **1020** is equal to the first predetermined delay. The first predetermined delay preferably corresponds to an empirically determined delay between transmission of a command to stop the meter **300-1** and the last seed from the meter **300-1** being sensed by the seed sensor **150**. At step **1030**, the planter monitor **190** preferably compares the time estimated at step **1020** to a second predetermined delay and commands the second drive **315-2** to start when the time estimated at step **1020** is equal to the second predetermined delay. The second predetermined delay preferably corresponds to an empirically determined delay between transmission of a command to start the meter **300-2** and the first seed from the meter **300-2** being sensed by the seed sensor **150**. In other embodiments, rather than using a first and second predetermined delay, the planter monitor **30** preferably simultaneously commands the first drive **300-1** to stop and the second drive **300-2** to start when the time estimated at step **1020** is equal to a switch delay. At step **1035**, the planter monitor preferably commands a speed to the second drive **315-2** based on an application rate map stored in the memory of the planter monitor and associating desired application rates with geo-referenced locations.

In other embodiments of the process **1000**, the planter monitor **190** commands both meters **300-1**, **300-2** associated with the row unit **200** to plant in a blended zone defining a region between two seed variety map regions calling for different seed varieties. In such embodiments, the planter monitor **190** preferably commands both meters to plant at half the rate associated by the application rate map with each location in the blended zone. It should be appreciated that such embodiments are beneficial when the first seed variety and second seed variety comprise soybeans. In some such embodiments, the seed variety map does not include a blended zone and the system **100** implements a blended zone at all locations within a predetermined distance (e.g., 20 feet) of a variety boundary.

In some embodiments, the planter monitor **190** is configured to receive an input from the operator placing the planter monitor in a "single input" mode wherein both bulk hoppers **110***a*, **110***b* are filled with the same seed type. In the "single input" mode, rather than executing the process **1000**, the planter monitor **190** commands the first seed meter to plant until an empty signal is received. Once the empty signal is received, the planter monitor **190** preferably commands the first meter to stop and commands the second seed meter to plant. The empty signal may comprise a signal from a sensor (e.g., an optical sensor or a scale) configured to generate a signal corresponding to the fill level of a bulk hopper or a row unit hopper. The empty signal may also comprise a signal from one or more seed sensors indicating that no seeds have been planted for a predetermined time or distance over which the first meter was commanded to plant.

In some embodiments of the process **1000**, the planter monitor **190** adjusts an angular position or velocity of one or more of the seed discs **320** in order to achieve a desired alignment of the seed discs. It should be appreciated that such embodiments may be useful when simultaneously planting with both seed discs **320** such that seeds on the first seed disc **320-1** do not contact seeds on the second seed disc **320-2**. In some desired alignments, the seed apertures **322** are not transversely adjacent to each other. In one such desired alignment, the angular positions of the seed discs **320** are offset by one half of the angle between neighboring seed apertures **322** on one of the seed discs. In some such embodiments, the planter monitor **190** adjusts the angular position or velocity of a seed disc **320** based on a disc alignment signal in order to achieve the desired alignment. Referring to FIG. **19**, the disc alignment signal may comprise a signal generated by a Hall-effect sensors **1900** disposed adjacent to the seed disc **320** and disposed to generate a pulse when a magnet **1910** mounted to the seed disc passes the Hall-effect sensor. In such embodiments, one such Hall-effect sensor is associated with both seed discs **320** on the row unit and the planter monitor **190** preferably slows or accelerates one of the seed discs **320** in order to achieve a desired time between subsequent pulses in the signals received from both a first Hall-effect sensor **1900-1** and a second Hall-effect sensor **1900-2**. In other embodiments, the seed pulse signal from the seed sensor **150** is used as a disc alignment signal; in such embodiments, the planter monitor **190** preferably slows or accelerates one of the seed discs **320** in order to achieve a desired time ratio (e.g., **1** to **1**) between subsequent seed pulses in the signal generated by the seed sensor **150**.

Although the foregoing description primarily describes systems, methods, and apparatus of input selection with respect to seed planting, it should be appreciated that the same systems, methods, and apparatus may be used to vary between types of other granular agricultural inputs such as granular fertilizer.

Single-Hybrid Operation Methods

The seed variety selection system **100** is preferably reconfigurable into a "single hybrid" mode in which the system is configured to plant a single seed type (e.g., single hybrid) from both bulk hoppers **110**.

Thus, referring to FIG. **34**, in some embodiments, the seed variety selection system **100** is configured to enable a reconfiguration process **3400**. At step **3405**, the seed lines **120** connecting the first bulk hopper **110-1** to a first subset of row units **200** are preferably blocked to air flow. In a preferred embodiment, the first subset of row units comprises all of the row units on the right-hand side of the planter. At step **3410**, the seed lines **120** connecting the second bulk hopper **110-2** to a second subset of row units **200** are preferably blocked to air flow. In a preferred embodiment, the second subset of row units comprises all of the row units on the left-hand side of the planter.

Each seed line **120** may be blocked manually by the operator using a removable plug in the seed line or at the pneumatic connection between the seed line and the seed meter or entrainer outlet. Alternatively, each seed line may be manually closed using a valve or closed via an electrically operated valve or actuator in electrical communication with the planter monitor **190**.

At step **3415**, the vacuum lines **172** connecting the vacuum source **170** to the meters disconnected from the first bulk hopper **110-1** at step **3405** (i.e., on the first subset of row units) are preferably blocked to air flow. At step **3420**, the vacuum lines **172** connecting the vacuum source **170** to the meters disconnected from the second bulk hopper **110-2** at step **3410** (i.e., on the second subset of row unites) are preferably blocked to air flow.

In some embodiments, instead of completely blocking vacuum flow to one of the meters on each row unit for operation in a single-hybrid mode, an orifice (not shown) is inserted into the vacuum line **172** connecting the vacuum source **170** to each meter disconnected from the first bulk hopper **110-1** in order to partially block air flow. In some embodiments, the orifice includes an opening sized to reduce the area open to vacuum flow by about 70%. In some embodiments, the orifice includes an opening sized to reduce air flow by approximately 75%. The pressure at the vacuum source **170** in operation of such embodiments may be approximately 20 inches of water in some implementations.

Each vacuum line **172** may be blocked manually by the operator using a removable plug in the vacuum line or at the pneumatic connection between the vacuum line and the seed meter or the vacuum source. Alternatively, each vacuum line may be manually closed using a valve or closed via an electrically operated valve or actuator in electrical communication with the planter monitor **190**. It should be appreciated that each vacuum line may be closed by a single valve or actuator disposed to close off air flow to each vacuum line.

In other embodiments, the system **100** is configured to enable operation in a single-hybrid mode in which the system alternately plants from the first bulk hopper **110-1** and the second bulk hopper **110-2**. In such embodiments, the system **100** the currently "active" bulk hopper (i.e., the bulk hopper being planted from at the current time) preferably distributes seed to one meter on each of the row units; after the bulk hopper switch is executed the next "active" bulk hopper preferably distributes seed to another meter on all of the row units. Thus, referring to FIG. **35**, in such embodiments, the system **100** is preferably configured to carry out a bulk hopper switching process **3500**.

At step **3505**, the system **100** preferably distributes seed from the first bulk hopper **110-1** to one of the seed meters (e.g., seed meter **300-1**) on each row unit **200** on the planter. At step **3510**, the system **100** preferably identifies a first bulk hopper switch criterion. Upon identifying the first bulk hopper switch criterion, at step **3515** the system **100** preferably "switches" to distributing seed from the second bulk hopper **110-2** to another seed meter (e.g. seed meter **300-2**) on each row unit **200** on the planter (e.g., by stopping the first meters **300-1** from metering seed and commanding the second meters **300-2** to meter seed).

The bulk hopper switch criterion of step **3510** may comprise any of the following: the planter being in a lifted configuration (e.g., determined by a lift switch signal or lift command); a predetermined number of passes executed (e.g., determined by directional change reported by the GPS receiver, a lift switch signal or lift command); a number of seeds dispensed (e.g., as counted by a seed sensor or estimated based on meter speed); a distance traveled (e.g., based on radar or GPS coordinates); or a time elapsed. In preferred embodiments, the bulk hopper switch criterion is met at regular and relatively close intervals (e.g. after each pass) such that the bulk hoppers have approximately equal weight during planting operations. In other embodiments, the bulk hopper switch criterion comprises a time elapsed without seed being sensed by one (or a plurality or all) of the seed sensors, such that the bulk hopper switch criterion is met only when the active bulk hopper has been substantially emptied.

At step **3520**, the system **100** preferably identifies a second bulk hopper switch criterion. Upon identifying the second bulk hopper switch criterion, at step **3525** the system **100** preferably "switches" to distributing seed from the first bulk hopper **110-1** to another seed meter (e.g. seed meter **300-1**) on each row unit **200** on the planter (e.g., by stopping the first meters **300-2** from metering seed and commanding the second meters **300-1** to meter seed).

The bulk hopper switch criterion of step **3520** may comprise any of those criteria recited with respect to step **3510** and preferably comprises the same criterion used at step **3510**.

It should be appreciated that the methods and apparatus for blocking airflow in unused vacuum lines and seed lines described above with respect to reconfiguration process **3400** may be implemented upon each bulk hopper switch in the bulk hopper switching process **3500**.

Vacuum, Seed and Data Connections

FIG. **36** illustrates an embodiment of a row unit **3600** having two seed meters **3630-1**, **3630-2** (only **3630-1** is visible in FIG. **36**) is illustrated in FIG. **36**. As described in connection with the previous embodiments, each seed meter **3630-1**, **3630-2** preferably includes a seed side housing **330** and a vacuum side housing **340**, identified by reference numerals **330-1**, **330-2** and **340-1**, **340-2** respectively for each of the seed meters **3630-1** and **3630-2** respectively. An auxiliary hopper **3632** preferably contains seed and supplies seed by gravity into the seed side housing **330** for planting by the seed meter **3630**.

Seed is preferably pneumatically supplied to the first auxiliary hopper **3632-1** from the first bulk hopper **110-1** and to the second auxiliary hopper **3632-2** from the second bulk hopper **110-2**. In the illustrated embodiment, a splitter **3640** associated with each auxiliary hopper **3632** receives seed from an auxiliary hopper on a first adjacent row unit (or on the left- or right-most row unit, directly from the bulk hopper) and supplies seed to another auxiliary hopper on a second adjacent row unit. In some embodiments, the splitter **3640** is configured to supply seed to the auxiliary hopper on the second row unit only after the auxiliary hopper associated with the splitter has been substantially filled with seed. In this way, the first bulk hopper **110-1** supplies seed to a first set of seed meters **3630-1** on each row unit and the second bulk hopper **110-2** supplies seed to a second set of seed meters **3630-2** on each row unit.

Vacuum is preferably pulled in the vacuum side housing **340** of each seed meter **340** via a vacuum port **342**. Each vacuum port **340** is preferably in fluid communication with a vacuum source **170** (e.g., a vacuum impeller) via a vacuum splitter **3650**. The vacuum splitter **3650** preferably includes a vacuum port **3652** in fluid communication with the vacuum source **170**, e.g., via flexible tubing. The vacuum splitter **3650** preferably includes a first splitter port **3654** in fluid communication with the vacuum port **340-1** of the seed meter **3630-1**. The vacuum splitter **3650** preferably includes a second splitter port **3656** in fluid communication with the vacuum port **340-2** of the seed meter **3630-2**.

In another embodiment illustrated in FIG. **37**, in connection with the previous embodiments, each seed meter **330**, identified by reference numerals **330-1**, **330-2**, and vacuum housing **340**, identified by reference numerals **340-1**, **340-2**, each vacuum housing **340** including a modified vacuum port **342'**. In some embodiments, the vacuum port **342'** is substantially rigid. The vacuum port **342'** preferably forms a sealed fluid coupling with the outlet splitter port (e.g., **3654** or **3656**). The outlet splitter port (e.g., **3654** or **3656**) is preferably fluidly coupled to the vacuum port **342'** as the vacuum side housing **340** is attached to the seed side housing **330**. The outlet splitter port (e.g., **3654** or **3656**) is preferably fluidly decoupled from the vacuum port **342'** as the vacuum side housing **340** is removed from the seed side housing **330**. In the illustrated embodiment, the outlet splitter port (e.g., **3654** or **3656**) is fluidly coupled to the vacuum port **342'** via contact between a resilient insertion member **3682** having a flexible annular flange (not shown) and a rigid receiving funnel **3684**; as the insertion member enters the funnel, a vacuum seal is formed between the two elements. In some embodiments, the insertion member and funnel **3684** are similar to those in the pneumatic quick coupling disclosed in U.S. Pat. No. 4,843,983, incorporated herein in its entirety by reference.

Returning to the row unit **3600** of FIG. **36**, in some embodiments, the row unit includes a common input **3670** through which a central processor or controller is placed in data (e.g., electrical) communication with two connectors **3671**. Each connector **3671** is preferably configured to be placed in data (e.g., electrical) communication with one of the drives **315**. In one embodiment, the common input **3670** comprises a four-pin connector. A first and second pin are each in communication with high and low bus (e.g., CAN) communication lines which preferably carry motor speed commands and encoder measurements to the drive **315-1** associated with seed meter **3630-1**. A third and fourth pin are each in communication with high and low bus (e.g., CAN) communication lines which preferably carry motor speed commands and encoder measurements to the drive **315-2** associated with seed meter **3630-2**.

Turning to FIG. **38**, an alternative variety selection system **100'** is illustrated schematically. In addition to the components of the variety selection system **100** described above, the alternative variety selection system **100'** preferably includes one or more reducing actuators. The reducing actuators are preferably disposed and configured to reduce seed flow to a subset of row units on the implement; for example, the reducing actuators may reduce seed and/or air flow to or from one or more bulk tanks on the implement.

An upstream reducing actuator **3810** may be provided upstream of and in fluid communication with the entrainers **115** for selectively reducing air flow from the pressure source P (e.g., an impeller) to one or both of the entrainers **115**. In some embodiments, the reducing actuator **3810** comprises a single reducing device (e.g., a reducing device having an inlet in fluid communication with the pressure source P, a first outlet in fluid communication with the first entrainer **115***a*, and a second outlet in fluid communication with the second entrainer **115***b*), while in others the reducing actuator **3810** may comprise two devices (e.g., a first reducing device in fluid communication with a pneumatic line fluidly connecting the pressure source P and the first entrainer **115***a* and a second reducing device in fluid communication with a pneumatic line fluidly connecting the pressure source P and the second entrainer **115***b*).

A downstream reducing actuator **3820** may additionally or alternatively be provided downstream of and in fluid communication with the entrainers **115** for selectively reducing air flow from one or both of the entrainers **115** to the seed meters **300**. In some embodiments, the reducing actuator **3820** comprises a single reducing device or a plurality of reducing devices.

The reducing device or reducing devices of the reducing actuators **3810**, **3820** may comprise a device suited to reduce (e.g., block, divert or vent) air flow to a subset of seed meters **300**. As non-limiting examples, the reducing device may comprise a selectively positionable valve (e.g., an on-off valve, a directional valve, or a butterfly valve) or a selectively positionable vent or gate. The reducing valve may vent air from a pneumatic line to atmosphere, reduce an amount of air permitted to enter a pneumatic line, or direct air toward a first pneumatic line and away from a second pneumatic line.

The reducing actuators **3810**, **3820** preferably additionally include actuating devices for selectively modifying a position or other operating characteristic of the reducing device in order to select a position of the reducing device and thus selectively reduce air flow to a subset of seed meters. Each actuating device is preferably in data (e.g., electrical) communication with the planter monitor **190**; the planter monitor preferably sends command signals to the actuating device in order to select a position or operating characteristic of the reducing device. The actuating devices may comprise an electrically-operated spool (e.g., for changing a position of a valve), an electrically-operated linear actuator, an electric motor (e.g., for changing the position of a vent, gate or valve).

In operation, one or both of the reducing actuators **3810**, **3820** are preferably actuated in order to reduce flow to a subset of seed meters that are not planting and/or will not be planting seed until a threshold time or distance passes, or will plant less than a threshold amount of seed over the next threshold time period or distance; this actuation preferably reduces the amount of seed built up in non-planting seed meters and in pneumatic lines fluidly connecting an entrainer to a non-planting seed meter. For example, if only one type of seed will be planted in the next 50 yards of implement travel, a reducing actuator is preferably actuated such that air flow through the entrainer associated with the other type of seed is reduced. In some embodiments, the reducing actuators are actuated manually by the operator. In other embodiments, the operator enters a user input into the planter monitor **190** such that the planter monitor sends a command signal to the reducing actuator causing the reducing actuator to reduce flow to the non-planting seed meters. In a preferred embodiment illustrated in FIG. **39**, the planter monitor automatically actuates the reducing actuator or reducing actuators.

Turning to FIG. **39**, a process **3900** for actuating a reducing actuator is illustrated. At step **3905**, the planter monitor **190** preferably identifies a single-hybrid planting condition (e.g., an operating condition in which it is desirable to reduce flow of seeds to a subset of seed meters). The single-hybrid planting condition may comprise an operating condition in which seed from only one of the bulk hoppers **110** is being planted or has been planted during a preceding time period, planting area or travel distance. The single-hybrid planting condition may comprise an operating condition in which less than a threshold amount of seeds (e.g., seeds per acre, seeds per time, seeds per distance) from one of the bulk hoppers **110** is being planted or has been planted during a preceding time period, planting area or travel distance. The single-hybrid planting condition may comprise an operating condition in which none or less than a threshold amount of seeds (e.g., seeds per acre, seeds per time, seeds per distance) will be planted.

Turning to FIG. **39**, a process **3900** for actuating a reducing actuator is illustrated. At step **3905**, the planter monitor **190** preferably identifies a single-hybrid planting condition (e.g., an operating condition in which it is desirable to reduce flow of seeds to a subset of seed meters). The single-hybrid planting condition may comprise an operating condition in which seed from only one of the bulk hoppers **110** is being planted. The single-hybrid planting condition may comprise an operating condition in which none or less than a threshold amount of seed is predicted to be planted from one of the bulk hoppers **110** over the following threshold time or travel distanced. The amount of seed predicted to be planted from each of the bulk hoppers **110** may be estimated based on a plurality of inputs including a prescription map (e.g., a multiple-hybrid prescription map associating seeding rates and seed types with each location in the field), the position of the implement, the travel direction of the implement, and the travel speed of the implement (e.g., the current travel speed or the average travel speed over a preceding threshold time). As an illustrative example, the planter monitor **190** may estimate that no seeds are going to be planted from the bulk hopper **110***a* during the next 40 yards of travel distance by determining that the prescription map does not call for the seed type in bulk hopper **110***a* to be planted in any location along the travel direction of the implement between the current location of the implement and 40 yards from the current location of the implement. If the threshold minimum distance used to identify a single-hybrid planting condition is greater than 40 yards (e.g., 50 yards), then the planter monitor **190** preferably identifies a single-hybrid planting condition.

At step **3910**, once a single-hybrid planting condition has been identified, the planter monitor **190** preferably sends a command signal commanding the reducing actuator to change an operating state such that seed and air flow is reduced to the seed meters in communication with the bulk hopper having the seed type that was not being planted, is not being planted or is not predicted to be planted as described in step **3905**. For example, a gate, valve or vent may be moved in order to reduce or stop flow to the non-planting bulk hopper.

At step **3915**, the planter monitor identifies a multiple-hybrid planting condition (e.g., a planting condition in which a single-hybrid condition as described in step **3905** cannot be identified.)

At step **3920**, upon identifying a multiple-hybrid planting condition, the planter monitor **190** preferably sends a command signal commanding the reducing actuator to change an operating state such that seed and air flow is restored to the seed meters (e.g., to the reducing actuator position prior to step **3910**).

The foregoing description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred embodiment of the apparatus, and the general principles and features of the system and methods described herein will be readily apparent to those of skill in the art. Thus, the present invention is not to be limited to the embodiments of the apparatus, system and methods described above and illustrated in the drawing figures, but is to be accorded the widest scope consistent with the spirit and scope of the appended claims.

What is claimed is:

1. A method of operating an agricultural seed planter, the method comprising:

opening a planting trench in a soil surface with a row unit while advancing the row unit in a forward direction of travel, the row unit comprising:

a seed meter disposed to plant seeds in the trench;

a first bulk seed hopper configured to carry seeds;

a second bulk seed hopper configured to carry seeds;

a first entrainer in fluid communication with the first bulk seed hopper and the seed meter;

a second entrainer in fluid communication with the second bulk seed hopper and the seed meter; and

a reducing actuator in fluid communication with the first entrainer and the second entrainer;

providing an air flow from a pressure source through the reducing actuator, the first entrainer, and the seed meter;

entraining seeds from the first bulk seed hopper in the first entrainer with the air flow;

dispensing seeds from the first bulk seed hopper through the seed meter to the planting trench without dispensing seeds from the second bulk seed hopper through the seed meter;

changing a configuration of the reducing actuator;

providing the air flow from the pressure source through the reducing actuator, the second entrainer, and the seed meter;

entraining seeds from the second bulk seed hopper in the second entrainer with the air flow; and

dispensing seeds from the second bulk seed hopper through the seed meter to the planting trench without dispensing seeds from the first bulk seed hopper through the seed meter.

2. The method of claim **1**, wherein changing a configuration of the reducing actuator comprises reducing an amount of air flow to the first entrainer.

3. The method of claim **1**, wherein changing a configuration of the reducing actuator comprises increasing an amount of air flow to the second entrainer.

4. The method of claim **1**, wherein changing a configuration of the reducing actuator comprises moving the reducing actuator from a first position to a second position.

5. The method of claim **1**, wherein changing a configuration of the reducing actuator comprises venting air from the pressure source to atmosphere.

6. The method of claim **1**, further comprising directing seeds dispensed from the seed meter to the planting trench with a seed tube.

7. The method of claim **1**, further comprising directing seeds dispensed from the seed meter to the planting trench with a seed conveyance device.

8. The method of claim **1**, further comprising identifying a single-hybrid planting condition and generating a command to switch from planting the seeds from the first bulk hopper to planting seeds from the second bulk hopper upon identifying the single-hybrid planting condition.

9. The method of claim **8**, further comprising dispensing seeds from only one of the first bulk seed hopper or the second bulk seed hopper at one time during the single-hybrid planting condition.

10. The method of claim **8**, further comprising dispensing seeds from only one of the first bulk seed hopper or the second bulk seed hopper while traversing a travel distance during the single-hybrid planting condition.

11. The method of claim **1**, wherein no seeds flow through said the reducing actuator.

12. The method of claim **1**, further comprising controlling a rate at which seeds are dispensed by the seed meter with at least one electric motor.

13. A method of operating an agricultural seed planter, the method comprising:

opening a planting trench in a soil surface with a row unit while advancing the row unit in a forward direction of travel, the row unit comprising:

a seed meter disposed to plant seeds in the trench;

a bulk seed hopper configured to carry seeds;

an entrainer in fluid communication with the bulk seed hopper and the seed meter; and

a reducing actuator in fluid communication with the entrainer;

providing an air flow from a pressure source through the reducing actuator to the entrainer;

entraining seeds from the bulk seed hopper in the entrainer with the air flow from the pressure source;

dispensing seeds from the bulk seed hopper through the seed meter to the planting trench;

changing a configuration of the reducing actuator to reduce the air flow to the entrainer;

stopping dispensing seeds from the bulk seed hopper while the air flow to the entrainer is reduced.

14. The method of claim **13**, further comprising changing the configuration of the reducing actuator to increase the air flow to the entrainer and restart dispensing seeds from the bulk seed hopper.

15. The method of claim **13**, wherein changing a configuration of the reducing actuator comprises moving the reducing actuator from a first position to a second position.

16. The method of claim **13**, wherein changing a configuration of the reducing actuator comprises venting air from the pressure source to atmosphere.

17. The method of claim **13**, further comprising directing seeds dispensed from the seed meter to the planting trench with a seed tube.

18. The method of claim **13**, further comprising directing seeds dispensed from the seed meter to the planting trench with a seed conveyance device.

19. The method of claim **13**, further comprising identifying a single-hybrid planting condition and generating a command to change the configuration of the reducing actuator upon identifying the single-hybrid planting condition.

20. The method of claim **13**, further comprising controlling a rate at which seeds are dispensed by the seed meter with at least one electric motor.

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